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See page 15. 8421

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See Advertisement page 103, April 30.

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See Advertisement page 142. 8187

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NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

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8143
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See Full Page Advt., page 91, April 30.

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Forgings, Castings, Bars, Sheets, Wire, Tubes.
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See half-page Advert. last week and next week. 8490

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See half-page Advertisement page 93, April 16.

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For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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An Association specially formed to look after the Interests of Foremen on their Supervisory Capacity. F 601

All communications to— R. W. REID, General Secretary. Head Offices— 81, High Holborn London, W.C.1.

UNIVERSITY OF LONDON.

Provisional Notice.—A Course

of four Advanced Lectures on "High-frequency Alternators for Radio-Telegraphy" by Monsieur Marius Latour, of Paris, has been arranged provisionally to take place at the Institution of Civil Engineers, Great George Street, S.W. 1, on May 26th, 27th, 28th and 31st, at 5.30 p.m. A further announcement will be made. The Lectures are addressed to advanced students of the University and others interested in the subject. Admission free.

P. J. HARTOG, Academic Registrar. G 276

Royal Corps of Naval CONSTRUCTORS.—A COMPETITIVE EXAMINATION for one or more

Posts as Probationary Assistant Constructor will be held at the ROYAL NAVAL COLLEGE, GREENWICH, in JUNE next.
The Regulations and full particulars of the salary, prospects of promotion, etc., may be obtained from the SECRETARY (C.R.), Admiralty, S.W. 1, to whom intending candidates must submit their names and full particulars of their educational and technical training and practical experience, not later than 17th May.

PRIVATE STUDENTS OF NAVAL ARCHITECTURE.

In conjunction with the above examination there will be a qualifying examination for the admission of Private Students of Naval Architecture to the Royal Naval College, Greenwich. Applications for the Regulations, etc., should be made as in the case of the examinations for the post of Probationary Assistant Constructors (see above).
Private Students are required to pay a fee of £30 a session whilst at the College. G 278

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successes by Correspondence Coaching. Several prizes. Sec. "O" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434, Offices of ENGINEERING.

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TENDERS.

AUCKLAND HARBOUR BOARD, NEW ZEALAND.

Tenders are Invited for the

CONSTRUCTION and SUPPLY of Five 1 Ton ELECTRIC CAPSTANS and SPARES for same.
Specifications and Drawings can be obtained on payment of a deposit of Two Guineas at the Office of the Board's Agents, Messrs. W. AND A. MCARTHUR, LTD., 16-19, Silk Street, Cripplegate, London, E.C. 2.
Tenders to reach Auckland by noon, on September 1st, 1920. F 725

GREAT NORTHERN RAILWAY COMPANY (IRELAND).

TO BRIDGE CONTRACTORS.

The Directors are prepared to receive

Tenders for the Supply and

DELIVERY of STEELWORK for the Reconstruction of two Bridges.
Drawings, Specification, Bills of Quantities, and Form of Tender may be obtained from the undersigned on payment of Two Guineas, which will be refunded on receipt of a *bona fide* Tender, accompanied by the Drawings.
Tenders made out on the Forms to be supplied by the Company should be delivered under sealed cover, endorsed "Tender for Bridges," to the undersigned not later than 10 a.m. on Monday, 14th June, 1920.
The Directors do not bind themselves to accept the lowest or any Tender.

J. B. STEPHENS, Secretary.

Amiens Street Station, Dublin, 1st May, 1920. G 324

CITY OF BELFAST.

ELECTRICITY DEPARTMENT.

The Corporation invite

Tenders for the Manufacture,

DELIVERY, and ERECTION at the Electricity Works, East Bridge Street, of a COAL HANDLING PLANT.
The Specification and other particulars may be obtained on application to Mr. T. W. BLOXAM, M.I.E.E., City Electrical Engineer, Belfast.
Tenders, upon the presented forms, must be lodged in the Town Clerk's Office, City Hall, Belfast, not later than Eleven a.m., on Wednesday, 19th May, 1920.
The lowest or any Tender not necessarily accepted. An official receipt must be obtained for every Tender delivered by hand. Tenders sent by post must be registered.

R. MEYHR, Town Clerk. G 345
3rd May, 1920.

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED, are prepared to receive

Tenders for the Supply of:—

BRIDGEWORK, One 70 ft. Span Overbridge (approximately 105 tons).
Specifications and Forms of Tender may be obtained at the Company's Offices, Finsbury Pavement House, E.C. 2.
Tenders, addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Bridgework," must be left with the undersigned at 91, York Street, Westminster, S.W. 1, not later than Two p.m., on Wednesday, the 26th May, 1920.
A charge, which will not be returned, will be made of 10/- for each copy of the Specification. Copies of the Drawings may be obtained at the Office of ROBERT WHITE, Esq., M.Inst.C.E., Consulting Engineer to the Company, 3, Victoria Street, Westminster, S.W. 1.

By Order, W. B. REYNOLDS, for Managing Director.

Finsbury Pavement House, London, E.C. 2. 3rd May, 1920. G 334

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD. (PLANT AND MACHINERY SECTION).

For Sale by Public Tender.

GASHOLDERS AND TANKS, At H.M. AIRSHIP STATION, LONGSIDE.

TWO STEEL GASHOLDERS, each 250,000 cub. feet capacity.
Three LIFTS, Spiral Guided:
Inner Lift, 68 ft. 10 in. by 22 ft.
Middle Lift, 71 ft. by 22 ft.
Outer Lift, 73 ft. 2 in. by 22 ft.
Two STEEL TANKS, 75 ft. by 22 ft. 6 in.
Reference M.K. 24568/9. Gen. 2017.
Full particulars, permit to view, and Form of Tender upon application to the CONTROLLER (D.B.I.S.), Plant and Machinery Section, Charing Cross Buildings, Embankment, W.C. 2.
Tenders to be completed and returned not later than Ten a.m., 22nd May.

NOTE:—For particulars of other Government Property for Sale, see *Surplus*, price 3d., at all Bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 172

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD. (PLANT AND MACHINERY SECTION).

For Sale by Public Tender,

TOLUOL PLANTS, At MANCHESTER CORPORATION GASWORKS, Bradford Road, Manchester.

Six Tower Scrubbers, Carburettors, Steel frame Benzol House, Crude Still, Primaty and Secondary Rectification Stills, Oil and Water Coolers, Pumps, Two Boilers and One Pump, Chimney and Steel frame Boiler House, etc.

At NEEPSEND WORKS of the SHEFFIELD GAS CO.

Oil Tanks, Coils for Heat Exchanger, Oil Still, Pumps, Coolers, Condensers, Benzol Still, Benzol Washers, Acid and Soda Tanks, Rectification Still, Petrol Pumps, and Steel Frame Benzol and Exhauster Houses.

At GRIMESTHORPE WORKS of the SHEFFIELD GAS CO.

Heat Exchanger, Pre Heater, Oil Still, Receiver, Cooler, Condenser, Benzol Condensers, Pumps, and Steel frame Benzol House.

At GRANTON GASWORKS, EDINBURGH, and LEITH COMMISSIONERS.

Heat Exchangers, Oil Pumps, Coolers, Benzol Condensers, Crystallising Tanks, Pumps, Storage Tanks, etc.

At PROVAN GASWORKS, GLASGOW.

Heat Exchangers, Oil Pumps, Cooler, Pre Heater, Still, Benzol Still and Condenser, Condensers and Chimneys, Naphthalene Separators, Rectification Column, Benzol, Toluol, and Solvent Condensers, Pumps, Steel frame Plant House, Heavy Oil Still, Coolers, Spares, etc.

Detailed particulars, permit to View and Tender Forms, can be obtained on application to CONTROLLER, D.B.I.S., Plant and Machinery Section, Charing Cross Huts, Embankment, W.C. 2.
Tenders to be returned not later than 10 a.m. on the 20th May, 1920.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 220

METROPOLITAN BOROUGH OF HAMMERSMITH.

ELECTRICITY DEPARTMENT.

The Borough Council invite

Tenders for the Supply of

TWO 10,000 Kilowatt Maximum Continuous Rating TURBINES and Alternators, complete with Condensing Plant.
Specification and Form of Tender may be obtained from Mr. G. G. BELL, Borough Electrical Engineer, Electricity Works, 55, Fulham Palace Road, W. 6.
Sealed Tenders, endorsed "Tender for Turbines," must be delivered to the undersigned not later than Nine a.m., on Friday, 21st May, 1920.
The Council do not bind themselves to accept the lowest or any Tender.

LESLIE GORDON, Town Hall, Hammersmith, W. 6. Town Clerk. 27th April, 1920. G 204

SHEFFIELD CORPORATION WATER WORKS.

RIVER DON PUMPING SCHEME — CONSTRUCTION OF RESERVOIR.

Tenders are Invited for the

Construction of a BALANCING RESERVOIR, at Damflask, about 4 miles from Wadsley Bridge Station (G.C.Ry.), of a capacity of 5¼ million gallons.
Drawings and specification may be inspected, and schedule of quantities and Form of Tender may be obtained on application at the Water Works Office, Town Hall, Sheffield.
The Tender will incorporate Conditions of Contract, which provide (inter alia) for compliance with the Council's form of clauses respecting wages, hours and conditions of labour, and prohibition against assigning or sub-letting.
Tenders must be enclosed in sealed envelope, addressed to the undersigned, and endorsed "Tender for Damflask Balancing Reservoir," and received not later than Saturday, 22nd May.
The Corporation do not undertake to accept the lowest or any Tender.

WILLIAM TERREY, Waterworks Office, Town Hall, Sheffield. General Manager. 23rd April, 1920. G 144

TO CONTRACTORS.

GOSPORT AND ALVERSTOKE URBAN DISTRICT COUNCIL.

CONSTRUCTION OF LANDING STAGE, WHARF AND OTHER WORKS.

The Gosport and Alverstoke Urban District Council are prepared to receive

Tenders for the Construction

at Gosport, Hants, of a FLOATING LANDING STAGE, 200 ft. long by 30 ft. wide, connected with the shore by a Bridge 130 ft. long by 20 ft. wide, and Approach Roads leading thereto; about 550 lineal feet of Reinforced Concrete Retaining Walls to enclose portions of Gosport Hard and the adjoining foreshore; the filling in of the area so enclosed; the Removal of Gosport Hard; a Reinforced Concrete Wharf 300 ft. long by 150 ft. wide at Harbour Road; the necessary Dredging for the Landing-Stage and Wharf, and other contingent works.
The Contract Drawings and Specification may be seen at the Offices of the Engineers, SIR JOHN WOLFE-BARRY, LYSTER & PARTNERS, Dartmouth House, 2, Queen Anne's Gate, Westminster, S.W. 1, on and after Wednesday, 19th May, between the hours of Eleven and Four, and copies of the Drawings and Specification, together with a Schedule of Quantities and Form of Tender, may be obtained there upon payment of Five Guineas. This sum will be repaid by the Council upon receipt of a *bona fide* Tender, accompanied by the Specification and Drawings, which are to be returned with the Tender.
Tenders endorsed "Tender for Landing Stage, &c.," must be delivered under seal at the Office of the Clerk to the Gosport and Alverstoke Urban District Council, Council Offices, Gosport, Hants, on or before noon on Saturday, 5th June.
The lowest Tender will not necessarily be accepted.

H. R. MANGNALL, Clerk to the Council.

Council Offices, Gosport. 4th May, 1920. G 380

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD. (PLANT AND MACHINERY SECTION.)

FOR SALE BY TENDER

TANKS AND CISTERNS.

Tenders are Invited for the

following:—
M.K. 21382.—One STEEL BOILER TANK, 28 ft. long by 7 ft. dia., with two valves.
M.K. 21383.—One STEEL BOILER TANK, 28 ft. long by 8 ft. dia., with one valve.
M.K. 21384.—One STEEL BOILER TANK, 38 ft. long by 7 ft. 6 in. dia., with two valves.
M.K. 21385.—One STEEL BOILER TANK, 38 ft. long by 8 ft. dia., with two valves.
M.K. 21386.—Three STONE ACID STORAGE CISTERNS, composed of 5 in. Stone flags, bolted together with iron bolts. Internal dimensions 6 ft. by 6 ft. by 5 ft. deep, lined with 4½ in. acid brick wall.

Used for Acid Storage.

Lying at BROOKE'S CHEMICALS, LTD., LIGHTCLIFFE WORKS, Halifax.

Closing date for Tenders, Saturday, May 15th.
Application for Tender Forms, etc., should be made to the CONTROLLER, Plant and Machinery Section, Disposal Board, Ministry of Munitions, Charing Cross Buildings, Embankment, W.C. 2. Telephone—Gerrard 560, Ext. 143. Telegrams—"Mapiadis, Wire London."
NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 10

FOR SALE.

CLACTON URBAN DISTRICT COUNCIL.

ELECTRICITY DEPARTMENT.

PLANT FOR SALE.

The above Council

Offer for Sale the following

PLANT:—
Two Davey Paxman, 160 B.HP., each engine Double-Cylinder "Vis a Vis" Q Type GAS ENGINES, direct coupled to 100 Kw. Thomas Parker's compound direct current generators, four-pole machines, to give 220 amperes with voltage regulation from 460-500 volts.
The plant is complete and can be seen by appointment.
Full particulars can be obtained from Mr. GEORGE BROADHURST, A. M. Inst. E. E., Electrical Engineer and Manager, 14, Electric Parade, Clacton-on-Sea.
Tenders to be delivered to the undersigned, Clerk to the Urban District Council, Town Hall, Clacton-on-Sea, not later than noon, on Monday, 17th May, next.
The highest or any Tender not necessarily accepted.

GEO. T. LEWIS, Town Hall, Clacton-on-Sea. Clerk to the said Council. April 23nd, 1920. G 115

APPOINTMENTS OPEN.

UNIVERSITY OF BRISTOL.

Assistant Lecturer in Civil

ENGINEERING. £300—£10—£350.
For particulars and form of application, send at once stamped, addressed foolscap envelope, to the REGISTRAR of the Merchant Venturers' Technical College. G 312

SUNDERLAND EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

DEPARTMENT OF MATHEMATICS AND MECHANICS.

The Committee invite

Applications for the Position

of LECTURER in the Department of Mathematics and Mechanics. Applicants must possess a University Degree, or its equivalent, training in Mathematics and Experimental Mechanics, and teaching experience in a Technical Institution.
Particulars of appointment, with Scale of Salaries and Regulations Governing Appointments, may be obtained from the Principal of the Technical College, Sunderland.
Applicants must apply by letter, with reference or copies of recent testimonials, to the undersigned on or before Monday, 31st May, 1920.

HERBERT REED, Chief Education Officer.

Education Department, 15, John Street, Sunderland. G 301

BIRKENHEAD EDUCATION COMMITTEE.

BIRKENHEAD TECHNICAL SCHOOL.

Required in September, a Full

TIME TEACHER OF ENGINEERING SCIENCE, Mechanics, Heat and Heat Engines, including Lecture and Laboratory Work, for the first and second years (T3 and T4), of the Engineering Course.
The evening duties extend over five nights per week during the Session, September to May, in addition to which it is intended to establish a limited number of day classes.
A thoroughly Practical and Theoretical Training in Mechanical Engineering is essential, and preference will be given to applicants who have had teaching experience in Engineering Laboratories.
The commencing salary, including war bonus, will be £350 to £450 per annum, according to experience and qualifications.
A list of duties will be forwarded on application to the undersigned, to whom applications (accompanied by not more than three testimonials, together with the names of three gentlemen who may be referred to as to the applicant's Teaching qualifications, etc.), must be sent not later than the 22nd May next.

ROBERT T. JONES, Town Hall, Birkenhead. Secretary. 21st April, 1920. G 68

SUNDERLAND EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

SUPERINTENDENT OF TRAINING FOR CONTINUATION AND TECHNICAL SCHOOL TEACHERS.

Applications are Invited for

the above POSITION, which is being established for the purpose of training intending teachers of Continuation and Technical Schools, who have had some experience in engineering works and shipyards. The Technical College provides full-time day advanced courses in engineering and science of a University type, and part-time courses in naval architecture, engineering, building, etc.
The Superintendent of Training will be required to organize (i) courses of training for students who have completed both their full-time day advanced courses in engineering, etc., and their apprenticeship; (ii) short courses for part-time technical teachers engaged in engineering works and shipyards; (iii) short courses for technical teachers already in the employ of the Committee; and (iv) such other duties as may be detailed by the Committee.
Candidates must possess a University Degree, or its equivalent, and it is desirable that he should have some knowledge of Technical School work, and also some experience in welfare work for boys.
Salary according to scale, £450–£25–£550.
Applications, accompanied by three recent testimonials and references, must reach the undersigned by June 5th, 1920.

HERBERT REED, Chief Education Officer.

Education Department, 15, John Street, Sunderland. G 300

REDUCTION GEARING ON STEAMSHIPS.

THE phenomenal success of the earlier installations of reduction gearing on turbine-driven steamships has of late met with a check owing to the fact that certain gears recently fitted have suffered excessive wear in service. It is noteworthy, however, that the failures are confined to double reduction gears, whilst single reduction gears still continue to give satisfaction in spite of large increases in the load imposed on the teeth and in the pitch line speed. In one case in which 18,500 h.p. is transmitted through a single pinion the pitch-line speed is 132 ft. a second and the load per linear inch of pinion face is over 1,000 lb. In another installation this load is 1,145 lb. per linear inch, and the pitch-line speed is 125 ft. a second. Breakages have been astonishingly few, and where they have occurred have been traced to faults in the material or in the minor details of the design. In his recent valuable contribution to the proceedings of the Institution of Naval Architects, Commander Tostevin stated that out of a total of 556 sets of single reduction gears supplied to the Navy only three have had to be removed for refit, and this necessity arose not from any failure of the gearing proper but to the fact that owing to the straining of the hull of the ships during service, the turbine and gear shafts had got a little out of alignment. There have been only two cases of broken teeth in service, but on removal of the broken or cracked material the gears have continued to run satisfactorily.

In the mercantile marine single reduction gears have proved equally satisfactory. Merchant ships however, for the most part are low-speed vessels, and it is inconvenient to obtain with this system as high a gear ratio as is desirable if both turbines and propellers are to be driven at their respective best speeds. This has led to the adoption of double reduction gearing which in certain instances has proved quite satisfactory in service, but in other cases the wear has been excessive. These experiences have led to a demand for a decrease in the loads imposed on the teeth, but it is exceedingly questionable if such a policy is in any way well based. In fact, there is strong reason for believing that the loads now carried could be substantially increased, provided certain modifications were made in the design of the installation as a whole. In short, whilst the proposed reduction in the loads now imposed on the teeth would probably improve matters, it seems practically certain that the benefit would in the main be due merely to the fact that the weight of the last motion wheel would be increased. There are, however, cheaper methods of securing flywheel effect than that of merely increasing the diameter or length of this wheel.

The trouble with double reduction gears appears to be confined to the second motion or slow-speed pinion, which in some cases has worn seriously during a comparatively short period of service. The high speed or first-motion pinion, designed to the same constants, has shown as little wear as in single reduction gearing.

This feature has led several engineers to the probably well-founded belief that it is the variation in the propeller torque which is in the main responsible for the trouble. In the December issue of *International Marine Engineering*. Mr. W. L. Emmet states that gears have failed at sea under loads less than one-quarter of what similar gears have, in land service, carried without trouble. He mentioned incidentally that with an experimental gear tested on land by the General Electric Company, a load of 3,000 lb. per square inch was borne without trouble, the pitch-line speed being 116·6 ft. per second. As indicative of the extraordinary variations which may arise in propeller shaft torque he gave the diagram which we reproduce in Fig. 1. This was recorded by a torsionmeter on a ship steaming in ballast through a fairly rough sea. Whether this can be considered a fairly representative case or not, it at least does show that the propeller torque may be expected to vary cyclically through a large range. With a single reduction gear the wheel on the propeller shaft is necessarily large and heavy, and its inertia must greatly reduce the shocks transmitted to the teeth. A single shock even of extreme violence does it would seem little damage.

In a recent discussion at the North-East Coast Institute of Engineers and Shipbuilders, Mr. J. C. Blackburn stated that whilst steaming at full speed the King Orry passed over a submerged rock. In doing so she lost all the blades of one propeller, and the propeller shaft was bent so much that it jammed. Nevertheless the gearing escaped unscathed.

On the other hand there is some very conclusive evidence that high speed gearing does not stand up well to large and repeated fluctuations in the load, such as might arise if the cyclical fluctuations in the propeller torque reached the teeth of the wheels undamped by the inertia of heavy revolving parts.

In our issue of October 24 last, page 555, we gave particulars of a case in which de Laval gearing (which is in general a very reliable piece of mechanism) gave way repeatedly under conditions which were apparently in no way abnormal. The gear transmitted 425 h.p. to an air compressor and failed repeatedly in service, having to be replaced no less than five times in six years. Ultimately it was discovered that the actual variations in the compressor torque were very materially higher than had been supposed, and when the compressor in question was replaced by a Reavell machine requiring a nearly uniform torque under all conditions of service, the trouble ceased. It is noteworthy that in this instance the final drive was taken through a belt. This would act very much in the same way as an elastic coupling, yet the teeth failed as stated.

This experience affords strong confirmation of the view that the at times unsatisfactory behaviour of

Fig. 1.

double reduction gears is due to insufficient inertia at the last motion or propeller shaft. In the early 'eighties the Holt Line of steamers were commonly provided with single-crank engines, having a large flywheel mounted on the propeller shaft. Marine engineers who ran these engines declared that their behaviour at sea was exceptionally satisfactory.

It will be an exceedingly interesting case of history repeating itself should present troubles lead to a reintroduction of this or an equivalent expedient on ships fitted with double reduction gearing. Certainly such a reversion would be less costly than the alternative advocated in some quarters of reducing the nominal load on the teeth.

The fact that the trouble experienced has been in the nature of excessive wear, and not lack of strength, raises anew the question as to the rational relationship between the diameter of a gear wheel and the permissible load on the teeth. American engineers have held from the outset that the load imposed should vary in direct proportion to the diameter of the pitch circle. In this country the load per inch run of pinion face has commonly been calculated from the equation:

$$W = C\sqrt{d} \text{ (lb. per inch run).}$$

Here W denotes the load in pounds per linear inch, d the diameter of the pinion in inches and C a coefficient, which originally fixed at 170 has, in at least one successful installation, been as high as 308. In his discussion on Mr. Walker's paper, read last December before the North East Coast Institute of Engineers and Shipbuilders, Mr. S. S. Cook attributed the adoption of this rule to a conservative desire to err, if at all, on the side of safety, when fixing the proportions of large gears on the basis of experience with small installations.

During the last couple of years we have learnt a great deal about lubrication which was previously unknown, and these later researches go far to confirm the American view (based, however on entirely different considerations) that the load imposed on teeth should vary directly as the diameter of the pitch circle and not in proportion to the square root of this diameter. The crux of the question depends upon whether there is or is not a minimum limit to the thickness of the lubricating film. For a given maximum intensity of pressure on the teeth the minimum thickness of the oil film does vary nearly in proportion to the square root of the pinion diameter. Recent work, however, indicates that for practical purposes there is no minimum limit to film thickness, as it has been proved that lubrication is possible with a film of which the thickness is a few molecules only, that is to say with a film of which the thickness is but a small fraction of one-millionth of an inch. Failure of gear teeth for other reasons than the breakdown of the lubrication would occur long before the film of oil between the teeth was reduced to such a thickness as this.

Nevertheless, even if as our present knowledge suggests, the square root rule is irrational, its adoption has probably been fortunate, as the importance of inertia in the propeller shaft wheel was for the most part unsuspected. The very moderate loading of large gears which has been a consequence of this rule, has resulted in the use of larger wheels on the propeller shaft than would have otherwise been provided, and the gain in inertia has apparently in the case of single reduction gearing been sufficient to prevent the teeth of this wheel, "overrunning," to any serious degree, the pinion teeth, as a consequence of the fluctuation in the propeller torque.

Whilst transmitting torque the teeth of the gear are under strain, and potential energy is stored up in them and in other parts of the gear just as it is when a spring is compressed. If the torque on the propeller shaft vanishes this potential energy becomes available for accelerating the last wheel of the gear, and if this be thereby flicked round faster than the driving wheels of the gear can follow up, the teeth will separate and will suffer a hammer blow on again coming into engagement. The stress developed on the concussion may be very high, and in excess of the elastic limit of the material. According to experiments made on mild steel rollers by Mr. J. Christie (Trans. Am.Soc.C.E., vol. xxxii) this limit is attained in static tests when the load taken in pounds per inch of "line contact" exceeds 1,600 R, where R is the radius of curvature of the roller taken in inches. In these experiments there was no effective lubrication, and in view of the effect of an oil film in distributing the pressure, gear teeth should be capable of carrying a somewhat greater load than the above before the elastic limit of the metal is exceeded. The mathematical theory of the behaviour of a lubricant when the teeth "hammer" leads to one result which may be put in a paradoxical form, viz.: In all conditions an infinite time must elapse before the metal surfaces of the teeth come into actual contact. Another and less startling statement of this result is, that it is impossible to squeeze out from between the surfaces the last molecules of the lubricant. Thus expressed, the conclusion seems not unreasonable, even though the assumptions on which the above mathematical deduction is based, fail to hold up to the bitter end.

As already noted experience indicates that a single concussion, even if very violent, will do little harm to the teeth of a gear, but under repeated blows the metal may shell off, and this is exactly what is found to occur. It is noteworthy, as confirming the view above put forward, that the teeth of marine reduction gears often suffer from pitting in the neighbourhood of the pitch point. This is exactly what might be expected. Since the deflection of a cantilever under load is proportional to the cube of the length, the stiffness of two teeth, considered as an elastic system, will be a maximum when the point of contact is near mid height, and will be much reduced when the point of one tooth bears near the root of the other. Hence, when hammering occurs the teeth in contact near the pitch point have to take far more than their fair share of the shock. It is noteworthy that some gears in which pitting has occurred continue to run satisfactorily. Presumably the process has in these cases worn down the surface near the pitch point, sufficiently to ensure that a tooth in engagement near its point

shall take a fair share of the shocks. Pitting would seem to arise from the hammering of the teeth, and to indicate that it would be advantageous to increase the rotary inertia of the propeller shaft or last wheel. Where pitting is absent another form of wear has been observed. The metal of the teeth becomes plastic under the pressure where this may be locally excessive and flows. The lubrication is, however, fully maintained, and for all practical purposes the teeth are uninjured. Plastic flow of this kind is probably largely responsible for the success of rigidly mounted gears. The teeth are able to wear themselves to a uniform bearing at full load without failure of the lubrication.

Whilst the addition of weight to the propeller shaft wheel appears to offer one solution of the problem of excessive wear, another and, if practicable, preferable method of reducing the risk of "overrunning" would be to diminish the angular momentum of the turbine rotor. It seems probable that one type of turbine may be more suitable for driving reduction gearing than another, and it is perhaps not without significance that the loads imposed on the teeth of de Laval gears are remarkably low. Thus, in the case of a de Laval turbine of 300 h.p., the pinion is 2·504 in. in diameter and the load carried is 64·8 lb. per inch of pinion face. The stress at the root of the teeth due to bending is but 1,165 lb. per square inch. In most marine reduction gears, the corresponding figure ranges from 4,000 lb. to 6,000 lb. per square inch, and in one installation it is as much as 8,500 lb. per square inch. In this case the pinion is 10·7 in. in diameter, the pitch-line speed 125 ft. a second, and the load carried per inch width of pinion face 820 lb. The wide discrepancy between these figures and those adopted in proportioning de Laval gears certainly requires accounting for, and the most obvious explanation is to attribute it to the high angular momentum of the turbine wheel. This wheel cannot readily change its speed, and thus if large fluctuations occur in the torque on the driven shafting the teeth will "overrun" each other and be destroyed by the consequent mutual cold hammering.

It would be of great interest to know whether gear troubles have been most common with reaction or with impulse turbines. If there is any difference in this regard it will probably be found that the angular momentum of the one type of turbine rotor is higher than that of the other.

The mathematical theory of the lubrication of gear teeth was worked out in an article published in our issue of August 16, 1916. This theory, it may be observed, is more directly applicable to gear teeth than to any other case of lubrication met with in practice. The effective width of the film under pressure is small in comparison with its length, and end flow of the oil is accordingly negligible. The teeth, moreover, come into gear intermittently. They have therefore time to cool between each successive engagement and the heat generated in the film is conducted away at each engagement by relatively cool metal surfaces. The viscosity of the oil should therefore remain more nearly constant than it does in other cases to which Reynolds' theory has been applied. Hence the calculated results of the theory should be directly applicable to practice with relatively little correction.

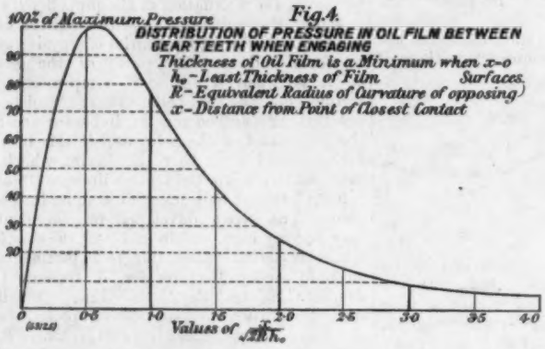
The relative motion of the two teeth in engagement with each other is in the main one of rolling, and is thus analogous to the motion of a cart wheel over a muddy road. The conditions accordingly differ greatly from those pertaining to journal lubrication. In the latter case the shearing stress in the film is a maximum at the point where the film is thinnest. This is not always true when the relative motion of the opposing surfaces is one of rolling, since although, mathematically speaking, the shear does attain a maximum at this point, there is a second and in some cases at least, a higher maximum elsewhere.

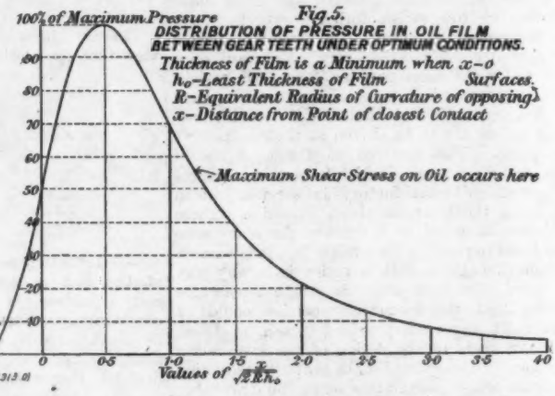
Again, in starting up a journal bearing from rest the layer of oil between the opposing surfaces does not act as a whole until a certain speed is attained. It is simplest to consider the case of a bush completely surrounding the journal. With the journal at rest, the point of nearest approach of journal and brass is immediately in the line of the load, as indicated in Fig. 2. In the stable running position, however, with the whole interspace filled with oil, all taking an effective part in the lubrication, the point of nearest approach is at right angles to the line of the load as represented in Fig. 3. Hence on starting up such a journal bearing in order to attain the position at which the film is operative as a whole it is necessary to lift the load. At the outset only a narrow band of the film directly under the load is effective for lubrication. When the load begins to lift, the then effective part of the oil film is thickened and loses its supporting power, and consequently the load falls back again, to be re-lifted by the greater pressure thereby developed in the film. This sort of alternation goes on until the speed attains a certain critical value at which the whole of the oil present in the interspace begins to act as a unit. The load is then permanently supported, and the point of nearest approach of journal and bush is at right angles to the line of the load as indicated in Fig. 3.

Nothing in any way analogous to this occurs in the case of teeth entering into gear. They approach each other both covered with a film of oil,

Fig. 2.

Fig. 3.


100% of Maximum Pressure
DISTRIBUTION OF PRESSURE IN OIL FILM BETWEEN GEAR TEETH WHEN ENGAGING
Thickness of Oil Film is a Minimum when x=0
h0=Least Thickness of Film
R=Equivalent Radius of Curvature of opposing Surfaces.
x=Distance from Point of Closest Contact
Values of x/√2Rh0
Fig. 4.


100% of Maximum Pressure
DISTRIBUTION OF PRESSURE IN OIL FILM BETWEEN GEAR TEETH UNDER OPTIMUM CONDITIONS.
Thickness of Film is a Minimum when x=0
h0=Least Thickness of Film
R=Equivalent Radius of Curvature of opposing Surfaces.
x=Distance from Point of closest Contact
Maximum Shear Stress on Oil occurs here
Values of x/√2Rh0
Fig. 5.

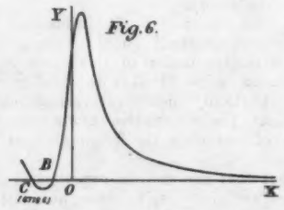


Fig. 6.

The velocity with which one surface rolls over the other, which is then squeezed out as the two surfaces roll over each other. This squeezing out is resisted by the viscosity of the lubricant.

In the article already cited *supra* it was shown that the curve representing the pressure in the film of oil might have the form represented in Fig. 4. This curve corresponds to the case in which the teeth are in the act of engaging. When disengaging the conditions are less favourable, and unless the tips of the teeth are rounded off the maintenance of the lubrication will be dependent here on the relative sliding of the teeth and not on their relative roll. When fully engaged the pressure curve may be of a more effective type, and under the best conditions may have the form represented in Fig. 5. In this case the load carried is a maximum for a stated value of h_0, which represents the minimum thickness of the oil film. Another possible form of the pressure curve is indicated in Fig. 6. In this case it will be seen there is a negative loop on the "trailing" side of the point of closest contact.

The equation to the curve represented in Fig. 4 (all quantities being taken in C.G.S. units) is:

$$P = \frac{\lambda u_0}{h_0^2} \cdot \sqrt{2 R h_0}\ (\sin 2\alpha + \tfrac{1}{2}\sin 4\alpha)$$

Here P denotes the pressure in dynes per square centimetre, λ the absolute viscosity of the oil in C.G.S. units, and h_0 the least thickness of the oil film, in centimetres. The velocity with which one surface rolls over the other is represented by u_0, and is expressed in centimetres per second. For involute gearing this rolling velocity is approximately one-third of the pitch-line speed. R denotes the equivalent mean radius of curvature of the teeth, expressed in centimetres. For involute teeth the value of R may be taken as given by the following equation:

$$\frac{1}{2R} = \left[\frac{1}{D_0} + \frac{1}{D_1}\right] \sin\theta \cos\phi.$$

Here D_0 is the diameter of the pitch circle of the pinion and D_1 the diameter of the wheel, whilst θ denotes the angle of obliquity or pressure angle of the teeth and ϕ the angle the helix makes with the axis of the wheel. With modern gears in which the angle of the helix, to which the teeth are cut, is 30 deg., the value of θ is about $16\frac{1}{2}$ deg.

Finally, α is defined by the equation:

$$\tan\alpha = \frac{x}{\sqrt{R h_0}}$$

where x denotes the distance in centimetres of any point in the film from the point of closest contact.

When the distribution of the pressure is that represented in Fig. 5, its value is given by the expression:

$$P = \frac{\lambda u_0}{h_0^2}\sqrt{2 R h_0}\left[0.4841\left(\frac{\pi}{2} - \alpha\right) + 0.6773\sin 2\alpha - 0.4597\sin 4\alpha\right]$$

As already stated, in this case the load carried for a given value of h_0 is a maximum. This distribution of pressure is not possible when the point of contact is at the end of a tooth. Owing, however, to the fact that the teeth are elastic, the load imposed on the teeth is greater when they bear in the neighbourhood of the pitch point than

elsewhere. Here the action is practically one of pure rolling without the sliding of one surface over the other, so that the assumption made in working out the mathematical theory is almost strictly true for the region in which the surface of the teeth is most heavily loaded, and in this region the distribution of pressure represented by Fig. 5 is possible.

In that case the load carried by a tooth is:

$$W = \frac{4.896 \lambda u_0 R}{h_0} \text{ dynes per cm. run.}$$

If R and h_0 be expressed in inches and u_0 in feet per second, this becomes:

$$W = \frac{\lambda u_0 R}{1,180\, h_0} \text{ lb. per in. run} \quad . \quad (1)$$

Here, as before, λ is to be taken in absolute C.G.S. units.

The maximum pressure occurs in the oil film at a point where $\frac{x}{\sqrt{2 R h_0}} = 0{\cdot}47517$, and is given by the relation (in C.G.S. units):

$$P_{max} = 1.521 \cdot \frac{\lambda u_0}{h_0^2} \cdot \sqrt{2 R h_0} \text{ dynes per sq. cm.}$$

or, taking u_0 in feet and linear dimensions in inches:

$$P_{max} = \frac{\lambda u_0}{3,780} \cdot \frac{\sqrt{2 R h_0}}{h_0^2} \text{ lb. per sq. in.} \quad . \quad (2)$$

Taking a case in which $\lambda = 0{\cdot}7$, $u_0 = 20{\cdot}3$ ft. per second and $R = 2{\cdot}75$ in. we find from (1) that if the load on a tooth amounts to 267 lb. per inch run, then h_0, the least thickness of the oil film, is $\frac{1}{8,050}$ in., and with this value of h_0 equation (2) gives 6,376 lb. as the maximum pressure within the oil film.

From (2) the stress on the metal varies proportionately to the square root of R, provided that there be a definite minimum limit to the thickness of the oil film. Observations made during the past four years prove, however, that lubrication may be perfectly maintained under oil film pressures so high that the metal flows. Thus in motor-car worm gears, although the efficiency of some of these gear is 96 per cent. or so, the phosphor-bronze of the wheel gradually flows under the pressure in the oil film, which must therefore attain a limit of full 30 tons per square inch. Moreover, the late Lord Rayleigh proved that a film only a few molecules thick could act as a lubricant, and since a film of oil 100 molecules thick would measure less than one-millionth of an inch, it is obvious that in general there is no practical limit to the minimum thickness of an oil film, as failure from too high a stress on the metal will occur long before the film becomes too thin for Reynolds' equations to be applicable.

Recent experiments have indicated that the difference between a good lubricant and a bad one lies in a good lubricant adhering more firmly to metallic surfaces than does a bad one. A good lubricant welds itself to the surface lubricated, and it seems probable therefore that the lubrication breaks down when the shearing stress on the film is so great as to break the bond so that the ultimate layer of the lubricant slips over the metal surface, whilst the theory assumes that there is no slip. If this view be well based the permissible load on gear teeth per inch run should be proportional to R as above defined, instead of in proportion to the square root of R.

The shear is a maximum at the point of inflection of the pressure curve, which for the case represented in Fig. 5 occurs on the "leading" side of the point of contact, when

$$\frac{x}{\sqrt{2Rh_0}} = 1{\cdot}205$$

whilst the point at which the opposing surfaces most nearly approach each other occurs when $x = 0$.

For the case already taken above, in which $R = 2{\cdot}75$ in., $h_0 = \frac{1}{8,050}$ in. and $u_0 = 20{\cdot}3$ ft. per second, and the load carried is 267 lb. per in. of tooth, the distance of the point of maximum shear from the point of minimum thickness is 0·032 in. This value affords some idea as to the effective width of the oil film, since as Fig. 5 shows the pressure falls off rapidly beyond the point of contrary flexure.

The value of the maximum shear is:

$$S_{max} = 1.225 \frac{\lambda u_0}{h_0} \text{ dynes per sq. cm.}$$

or, taking u_0 in feet per second and h_0 in inches, we have

$$S_{max} = \frac{\lambda}{4,696} \frac{u_0}{h_0} \text{ lb per sq. in.} \quad . \quad (3)$$

For the case already cited this equation shows that even under the very moderate loading and speed there assumed the shear stress tending to make the lubricant slip over the metal amounts to about 24½ lb. per sq. in. By substituting from equation (1), equation (3) can be put in the form:

$$S_{max} = \frac{0{\cdot}251\, W}{R} \text{ lb. per sq. in.}$$

so that if the limit of endurance is fixed by this maximum shear W should vary directly as R.

If hammering is unavoidable the damage done may well increase faster than the load on the teeth per inch run. For a given elastic system the energy stored in it varies as the square of the load. It is this energy that causes the teeth to separate, and it is at least a plausible assumption that the damage done on the return of the teeth should be proportionate to the energy expended in separating them. The moral would seem to be that cyclical hammering of the teeth is to be avoided at all costs, and that if this is done the load imposed may increase directly as the equivalent radius of curvature of the teeth surfaces.

The rise of temperature as the oil passes between the teeth of the gear is proportional to:

$$\frac{W^{\frac{1}{2}}}{R \cdot \sqrt{u_0 \lambda}}$$

and this may affect the adhesion of the lubricant to the metal. It may be prudent, therefore, to increase W, the load on the gear teeth, rather less than in direct proportion to the value of R.

In establishing the mathematical theory of lubrication it was assumed that the change of curvature of the surface of the teeth at the point of contact could be neglected. An approximate calculation of the amount of this elastic distortion shows that the assumption in question was perfectly sound.

To sum up, a review of the evidence at present available appears to indicate that recent gear troubles on shipboard have not been attributable to excessive loading of the teeth, but to the use either of too heavy turbine rotors, or to lack of inertia in the final wheel of the transmission. It would seem that the object of the designer should be to reduce to a minimum the angular momentum of the turbine rotor, and to increase the angular momentum of the last wheel of the gear as much as is commercially practicable. Unfortunately, the conclusions at which we have arrived are qualitative only. What is needed are figures setting forth the angular momentum of the turbine rotors and of the propeller shaft and wheel in the case of gears which have succeeded, and similar figures for gears which have failed. A comparison of these might yield information of the utmost importance to those responsible for designing marine reduction gears.

THE ARMSTRONG SHIPYARD.

(*Continued from page 569.*)

MOST of the remaining buildings in the yard are situated at the northern end, and are arranged with their greatest lengths at right angles to the fitting-out quay. The largest and most important of these is a steel-framed structure measuring 380 ft. long, 300 ft. wide and 30 ft. high to the eaves, and comprising the frame shed and anglesmith's shop. The latter runs across the whole width of the building at the eastern end, and is itself 80 ft. wide, so that the frame shed is actually 300 ft. square. A key plan with references showing the arrangement of the tools, cranes and other appliances in both shops, is reproduced in Fig. 135, on page 602, while two interior views of the frame shed are reproduced in Figs. 136 and 137, on Plate XXXIII.

The anglesmiths' shop contains two electrically-driven pneumatic power hammers, shown near the left hand bottom corner of Fig. 135 with a coal-fired furnace between them; these are mostly used for drawing packings and similar work. There are a number of pot fires and anvils for anglesmiths' work arranged in convenient groups along the centre and down one side of the shop. Blast is provided by three electrically-driven Keith and Blackman fans, which are designed to give an air pressure equivalent to a 22-in. column of water, and deliver air to the fires through underground ducts. These are arranged so that air can be supplied to any one of the groups of fires independently of the other groups. At the northern end of the shop is a gas-fired plate furnace, 10 ft. 6 in. long by 6 ft. wide, provided with bending blocks in front. Near this furnace is a hydraulic plate-flanging machine by Messrs. Hugh Smith and Co., Limited, having two 60-ton vertical overhead rams, and a smaller horizontal ram for squaring up flanges, &c. The width of the gap from the centre line of the vertical rams to the body of the machine is 4 ft., and there is also a 4-ft. clearance between the table of the machine and the bottoms of the rams when the latter are at the upper end of their stroke. An 80-ton hydraulic press for flanging and pressing work is also placed near the plate furnace. The large flanging machine is served by a 5-ton hydraulic crane, as shown in the key plan, and the crane equipment of the shop also includes another 5-ton hydraulic crane, used for handling heavy work from railway wagons, and a number of 10-cwt. hand cranes serving the hearths. One of these cranes is used in conjunction with an angle bending, cutting and straightening machine by Messrs. Craig and Donald, which is numbered 116 on the key plan. A considerable amount of electric and acetylene welding is carried on in this shop, and a special bay is partitioned off at the northern end for this purpose.

A considerable portion of the floor space in the frame shed, 22,000 sq. ft. to be exact, is occupied by the scrieve boards. On these boards the frames are laid out to full size for making the templates from which the set irons, or lines, are laid out on the bending blocks, so that the frames may be bent to the correct form. The photograph of the shed reproduced in Fig. 136, on Plate XXXIII, shows the scrieve boards in the foreground, while Fig. 137, on the same Plate, illustrates the furnaces and bending blocks at the other end of the shed. For heating the angle bars, from which the frames are formed, two double-ended bar furnaces, each 90 ft. long by 4 ft. wide by 3 ft. 6 in. deep, are provided, and there are also three plate furnaces, the largest of which will take a plate 36 ft. long by 13 ft. wide. These furnaces, it should be explained, are mainly employed for heating the plates for the stems and sterns of ships, but they also deal with any other plates which require furnacing. The doors of the large plate furnaces are fitted with hydraulic gear for opening and closing, and electric winches are provided for hauling the plates from these furnaces and the bars from the bar furnaces. All the furnaces are gas fired, gas being supplied by four Dowson-Mason producers, each capable of gasifying 10 cwt. of coal a day. Steam for the producers is supplied by two vertical boilers of the Cochran type. A bevelling machine is provided at each end of the bar furnaces for opening the angles of the frame bars so that the flanges conform with the line of the shell plating of the ship. These machines, which are by Messrs. Davis and Primrose, and are capable of bevelling angles up to 10 in. by 5 in. by 1 in. thick, are mounted on rails so that they can be moved into line with either furnace as required. The heated bars, after passing through the bevelling machine, are placed on the bending blocks, clamped at one end by iron dogs, and bent to the curve of the set iron by means of portable hydraulic frame setters. These tools, which, in effect, are horizontal hydraulic jacks mounted on wheels and provided with handles, can be distinguished in Fig. 137, on Plate XXXIII, which shows the work of frame bending in progress. When cold the frames are tested against the curves set out on the scrieve board, and, if necessary, returned to the bending blocks for adjustment.

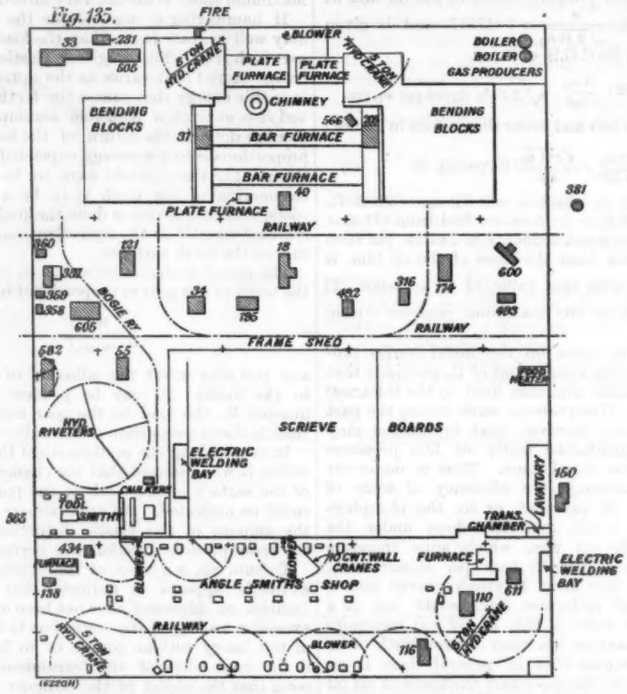
The machinery equipment of the shed includes a number of punching and shearing machines, angle cutters, manhole punches, drills, saws, &c., most of which are arranged in the centre of the shop, as shown in the key plan, Fig. 135, on page 602, but two sets of plate-bending rolls for forming masts,

and other tubular work of this class, are situated in the south-west corner near the plate furnaces. A portion of the shed to the left of the scrieve boards, in Fig. 135, is occupied by hydraulic riveting plant, the arrangement of which is similar to that at the heads of the building berths illustrated in Fig. 134, on page 582 *ante*. There are also a tool smithy and an electric welding bay in the shed. Two of the plate furnaces are served, respectively, by 8-ton and 5-ton hydraulic cranes of Messrs. Armstrong's own design and construction, which are similar in every way to those already mentioned when dealing with the platers' shed. Work is also handled by the yard locomotive cranes, one of which is shown in Figs. 136 and 137, on Plate XXXIII. For conveying frames between the bending blocks and scrieve boards overhead runways, of 30 cwt. capacity, are provided. The angles required in the frame shed are stored in angle racks on the northern side of the building, the racks being served by a 5-ton electric overhead crane of 120 ft. span. A hydraulic angle-bar shearing machine and a planing machine for angles are provided in convenient positions near the racks. The general sequence of work through the frame shed is as follows: The bars are taken from the racks and marked off for punching, and after punching and joggling, are taken to the furnaces; then, after bending on the bending blocks, they are conveyed to the scrieve boards for trial, and, if correct, the ends are faired and the frames delivered on to the berths by rail. Additional facilities for frame work are now being provided in the frame-punching shed referred to at the conclusion of our previous article. This building, which, as shown on the key plan, Fig. 1, on page 367 *ante*, is situated at the southern side of the frame shed, measures 130 ft. by 45 ft. and will be specially arranged for punching and joggling both frames and deck beams. There will be three machines in the shed—a double-ended duplex punch by Messrs. J. Bennie and Sons, and two Lambies' patent jogglers by Messrs. Hugh Smith and Co., Limited. The machines will be arranged so that two sets of men can work independently of each other, and this will allow four-frame furnaces to be kept going continuously. Overhead runways will be used for handling the frames in this shed and also for conveying them to the frame shed in which they will be bent and tried on the scrieve boards as mentioned above.

At the western end of the frame shed, and in close proximity to the railway tracks on which materials are brought into the yard, is a long, narrow building used for the preparation of deck beams; the building is actually 270 ft. long by 35 ft. wide. The rolled-steel sections, from which the beams are formed, are unloaded from the railway trucks and passed into the shed at the northern end by means of locomotive cranes. They are then marked off, punched and bevelled, or bent, as required, and delivered directly on to the berths from the other end of the shed. The building is equipped with a duplex punching machine and a hydraulic cropper, but the most interesting tool in the shed is the Arthur's patent bending machine, a photograph and drawings of which are reproduced in Figs. 140 to 142, on page 603. This machine, which was constructed by Messrs. Smith Brothers and Co. (Glasgow), Limited, of Glasgow, is capable of admitting beams up to 15 in. in depth, and is sufficiently powerful to form the usual deck camber of ¼ in. per foot on bulb angles, bulb tees, channels, zeds and other sections up to 13 in. deep. Lighter sections can, if required, be bent to a much smaller radius; for example bulb angles up to 9 in. deep can be bent cold to a radius of 6 ft., and 6 in. bulb angles can be bent to a 3-ft. 6-in. radius. The bending is performed by the three vertical rollers shown in the plan, Fig. 142, that marked Roller 1 being fixed in position while the other two are adjustable to alter the radius of curvature and to accommodate sections of different widths. The three vertical rollers are all driven by a 30-h.p. motor through gearing indicated by chain-dotted circles in Fig. 142, and a fourth horizontal loose roller is provided, as shown, to support the lower edge of the section while passing through the machine. The two adjustable rollers are mounted on blocks fitting in arc-shaped slots formed in the frame of the machine, the centre of the arcs coinciding with the axis of the gear wheel driving these rollers. It will be evident that the design ensures the gear teeth being kept in constant engagement for any position of the adjustable rollers. The latter are moved by links connected to a sliding crosshead worked by means of a large screw, a separate motor of 10-h.p. being provided for driving this mechanism. With this arrangement it is possible to alter the radius of curvature of a bar as it passes through the machine, and, consequently, a considerable portion of a ship's framing in which the curvature is not excessive could be set on the machine without furnacing, although it is not employed for this purpose at the Armstrong Yard.

Leaving, for the meantime, the blacksmiths' shop which adjoins the angle-racks, we propose

Fig. 135.



MACHINE TOOLS IN FRAME SHED AND ANGLESMITHS' SHOP.

18. Beam bending, horizontal punching and double angle-cutting machine.
31. Bevelling machine.
33. Plate bending rolls (mast rolls).
34. Hydraulic manhole punch.
35. Cold iron saw.
40. High speed saw.
121. Punch and shears.
150. Angle bar planer.
174. Punch and shears.
195. Hydraulic manhole punch.
209. Bevelling machine.
231. Winch.
316. Punch and shears.
357. Drilling machine.
358. Grinder.
359. Grindstone.
360. Grindstone.
381. Hydraulic bar shears.
492. Punch and shears.
493. Punch and shears.
505. Mast rolls.
565. Power hammer.
566. Winch.
582. Drilling and countersinking machine.
600. Double horizontal punching and angle-cutting machine.
605. Plate straightening machine.

ANGLESMITHS' SHOP.

110. Hydraulic plate-flanging machine.
116. Bending, angle-cutting and shearing machine.
138. Pneumatic power hammer.
434. Pneumatic power hammer.
611. Hydraulic press.

now to deal with the fitting shop which follows the frame shed, both in the matter of the dimensions of the building and of the importance of the work carried on in it. The building, which is a steel framed structure similar in character to those already described, has a length of 300 ft. and a width of 133 ft. It is divided into four bays, of which that on the southern side has a width of 44 ft., while the two central bays are each 28 ft. wide and the bay on the northern side is 29 ft. wide. Over two of the bays along the northern side, the building is in two storeys, the upper floor providing accommodation for the sailmakers, model makers and riggers. The sail loft is equipped with power-driven sewing machines for dealing with canvas work of all descriptions. As mentioned in the first article of this series, the fitting shop is particularly well equipped with heavy tools originally intended for warship work, and, although these may not all be so fully employed now that the yard is engaged in merchant shipbuilding, it is a distinct advantage to have them available for use at any time. Particulars of the tool equipment are given in the table of references accompanying the key plan, Fig. 143, on page 603. From this it will be seen that the tools are all arranged in the two bays on the south side of the shop, each of the bays being provided with a 10-ton electric overhead travelling crane; photographic views of these two bays are reproduced in Figs. 138 and 139, on Plate XXXIII. The tool equipment includes a number of modern lathes by Messrs. Lang and Sons and Messrs. Loudon Brothers, as well as Herbert turret lathes, Holroyd nut-tapping machines, and Heap bolt-screwing machines. There are also an "Acme" type surfacing, boring and facing machine, specially designed by Messrs. Dickinson for boring "A" brackets for vessels of moderate size, and some 42 in. Herbert sensitive radial drills, which are largely employed for drilling and tapping holes for ¼-in. screws used for fixing strips for securing the india-rubber facings on watertight doors. There are a number of Asquith radial drills, Muir's shaping machines, and Butler's slotting machines, two of the latter being visible on the left of Fig. 138 on Plate XXXIII. On the right of this view is a planing machine by Messrs. Loudon Brothers, Limited, of Johnstone, N.B., which is the only tool in the shop calling for special comment. This machine was specially designed for transverse, as well as longitudinal, planing, and is a particularly convenient tool for working on watertight doors, &c. It can accommodate work up to 14 ft. long by 7-ft. wide by 5 ft. 6 in. deep, and is driven by Lancashire electric equipment giving longitudinal cutting speeds ranging from 18 ft. to 72 ft. per minute, with a quick return of from 100 ft. to 150 ft. per minute; the transverse cutting speeds are two-thirds of the longitudinal speeds. The change-over from longitudinal to transverse planing is effected by means of a mechanically-operated clutch, the time taken for the operation being, of course, only a very small fraction of the time which would be occupied in re-setting the work. The bed and table are specially designed for the reception of heavy work, and the machine is arranged so that all operations, including

THE ARMSTRONG SHIPYARD.

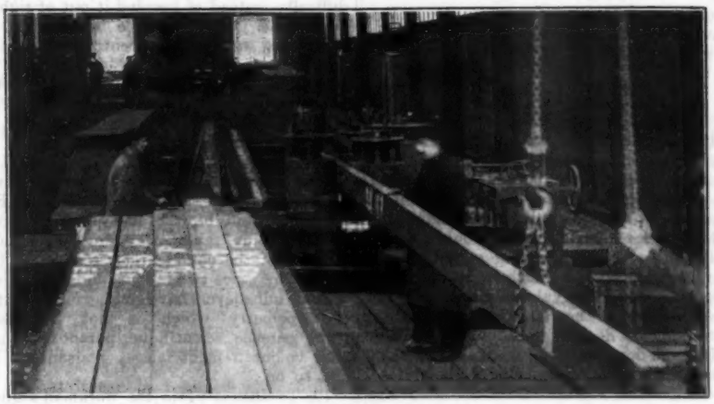
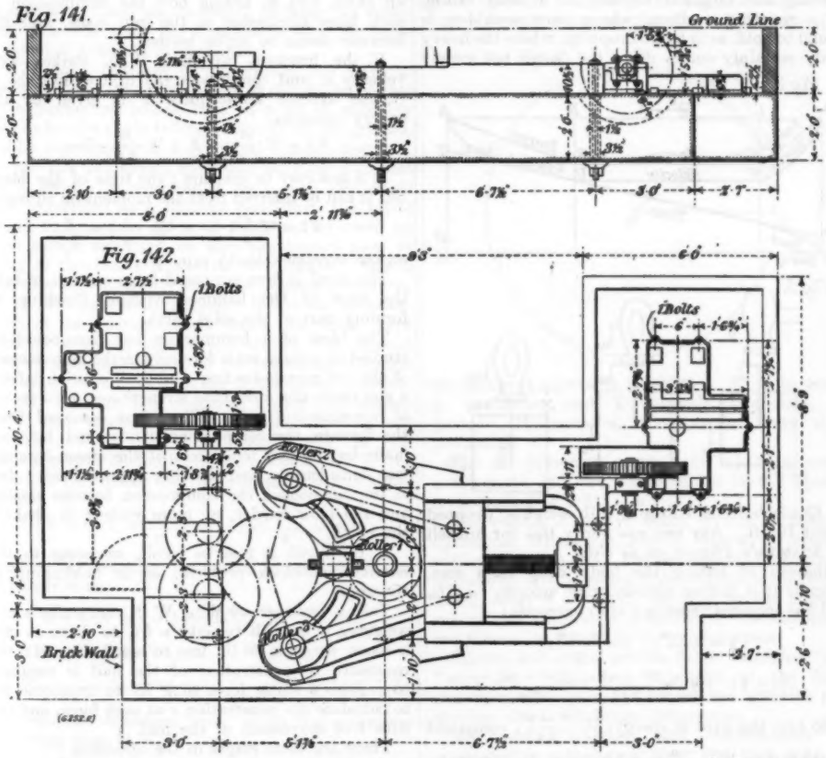


FIG. 140



FIGS. 140 TO 142. BEAM BENDING MACHINE; MESSRS. SMITH BROTHERS (GLASGOW), LIMITED, ENGINEERS, GLASGOW.

Fig 143

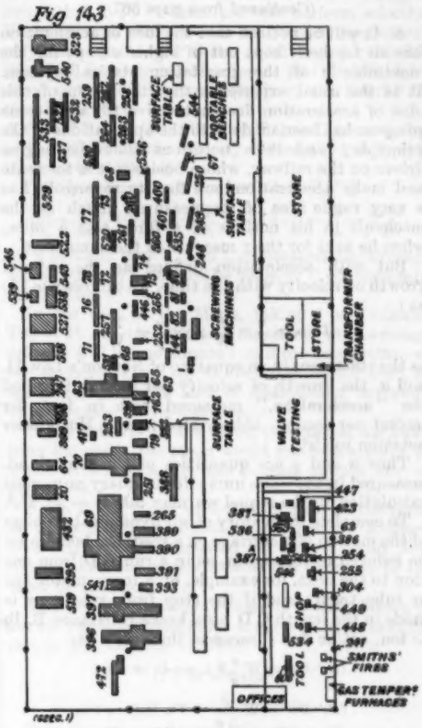


FIG. 143. FITTING SHOP.

MACHINE TOOLS IN FITTING SHOP AND TOOL SHOP.

20. Band saw.	258. Lathe.	528. Lathe.
63. Radial drill.	259. Lathe.	529. Lathe.
64. Radial drill.	260. Lathe.	530. Lathe.
65. Radial drill.	261. Lathe.	531. Lathe.
66. Radial drill.	262. Lathe.	532. Lathe.
67. Capstan lathe.	263. Lathe.	533. Lathe.
68. Milling machine	264. Lathe.	535. Turret lathe.
69. Planer.	265. Slotter.	538. Slotter.
70. Planer.	388. Radial drill.	539. Slotter.
71. Lathe.	389. Radial drill.	540. Planer.
72. Lathe.	390. Radial drill.	541. Radial drill.
73. Lathe.	391. Radial drill.	543. Radial drill.
74. Lathe.	392. Radial drill.	544. Sensitive drill.
75. Shaper.	393. Radial drill.	545. Drill.
76. Lathe.	394. Slotter.	550. Lathe.
77. Lathe.	395. Slotter.	
78. Lathe.	396. Planer.	TOOL SHOP.
79. Slotter.	397. Planer.	62. Milling machine
80. Bolt screwer.	398. Boring & facing machine.	241. Centrifugal fan.
81. Double bolt cutter.	399. Band saw.	254. Twist drill grinder.
82. Double bolt cutter.	400. Capstan lathe.	255. Cutter grinder.
83. Boring & facing machine.	401. Capstan lathe.	304. Wet tool grinder
144. Nut tapping machine.	417. Pipe flange facer	386. Vertical miller.
162. Grindstone.	432. Boring & facing machine.	387. Milling machine
247. Horizontal drill & tapping machine.	446. Radial drill.	387A Milling machine
248. Turret lathe.	472. Boring & facing machine.	423. Lathe.
249. Capstan lathe.	518. Boring & tapping machine.	447. Lathe.
250. Capstan lathe.	519. Slotter.	448. Drill.
251. Radial drill.	520. Lathe.	449. Drill grinder.
252. Drill.	521. Boring & facing machine.	534. Lathe.
253. Radial drill.	522. Radial drill.	536. Lathe.
256. Keyseater.	523. Planer.	546. Vertical miller.
257. Lathe.	526. Lathe.	562. Oscillating tool grinder.
	527. Lathe.	563. Plain cup grinder.
		606. Abrasive cutting-off machine

the starting and stopping of the table, are controlled from the front; safety switches are provided on both sides to prevent the possibility of over-running of the table. Another machine of the same type, but rather smaller and arranged for belt driving, is also provided. Most of the machines in the shop are belt-driven from line shafting carried on Hyatt roller bearings, but some of the larger tools are provided with independent electric motors.

About a half of the bay on the northern side of the shop is partitioned off to form a tool store and a store for finished parts, and a portion of the space is utilised for the hydraulic testing of castings for valves, &c. The remainder of this bay is occupied by the tool shop, in which the whole of the small tools, gauges, &c., required in the yard are made, adjusted and repaired. It is equipped with gas-fired hardening and tempering furnaces, a Herbert twist-drill grinder, and a universal grinder by the same makers, as well as a Lumsden oscillating grinder which is used for making lathe and planer tools by grinding from the bar without forging. For cutting up bars of high-speed steel for making tools, a 10-in. carborundum wheel, $\frac{1}{10}$ in. in thickness, and running at 4,600 r.p.m., is employed, and has been found to effect a considerable saving in time on this work. A Robey-Smith gear planer for mitre and bevel wheels, is also installed in the shop, as well as a number of engraving machines by Messrs. Taylor, Taylor and Hobson, of Leicester and by Messrs. T. Cooke and Sons, Limited, of York. One of these machines is specially arranged for marking degrees on steering dials, and other angular work of this character. A graduating machine, specially designed by Messrs. Armstrong for engraving gun rings, is also fitted in this bay. For checking the dimensions of gauges and of finished work, a large vernier caliper by Messrs. Troughton and Simms, Limited, is used. This instrument is fitted with agate-faced jaws, which can be adjusted by means of fine screws, and is capable of reading up to 60 in. by thousandths; a microscope is provided for reading the vernier.

Further storage space for finished fittings, in addition to that already referred to in the fitting shop, is provided in a building measuring 210 ft. long by 30 ft. wide, situated at the western end of the fitting shop and extending across the end of the blacksmiths' shop. This building, part of which is used as a test-house, is numbered 26 on the key plan of the yard printed on page 367 *ante*. Adjoining it is an engine shed 70 ft. in length and 25 ft. wide, which affords accommodation for six yard locomotives. Benches and tools are provided for use in connection with the overhaul and repair of the engines, and the work is further facilitated by pits formed between the rails.

(To be continued.)

COLLISION DYNAMICS.

By G. GREENHILL.

(*Continued from page 567.*)

8. It will be noticed that the idea of acceleration has so far been kept out of sight, except for the inevitable g of the gravitation statical system. It is the usual experience that the grasp of this idea of acceleration does not arrive till after some progress has been made with the applications of the principle; and it is notorious that the engine driver on the railway, whose business it is to create and make acceleration, and then to reverse it, has a very vague idea of its measure; much as the mechanic in his notions of a force and a blow, when he asks for their measure in the same unit.

But with acceleration defined as the rate of growth of velocity with the time, we can rewrite (A) as:

$$(D)\quad a = \frac{v}{t} = \frac{F}{W}\,g, \text{ or } \frac{a}{g} = \frac{F}{W}$$

as the statement in an equation of Newton's Law II, and a, the growth of velocity per second, is called the "acceleration," measured here in feet per second per second, abbreviated in the Hospitalier notation to f/s².

Thus a and g are quantities of the same kind, measured in the same unit; for ordinary numerical calculation in the sequel we may take $g = 32$, f/s².

To complete the history of our dynamical problem of the motion of a carriage on a road, the body must be reduced to rest again, as in a run A D from one stop to the next, for example, of a lorry, motor bus or tube train; and if the stop from velocity v is made in the length C D by a brake resistance B, lb or ton, acting for t' seconds through s' ft,

$$(A)'\quad B\,t' = W\,\frac{v}{g} = F\,t, \text{ sec-lb or ton};$$

$$(B)'\quad B\,s' = W\,\frac{v^2}{2g} = Fs, \text{ ft-lb or ton};$$

$$(C)'\quad \frac{s'}{t'} = \frac{1}{2}\,v = \frac{s}{t}, \text{ f/s}.$$

The middle part B C of the journey may be supposed run at full speed v, and then a graphical representation is given in Fig. 2 of a single journey from rest to rest, as of a graphical time table; with A K the total time; A T, G T' the time lost in starting and stopping, over T H, the time of running through at full speed without stopping.

A railway time table might be shown graphically on a similar scheme, except that the line of distance A D, marked with the stations, would run in the vertical margin to the left of the page, and time stretches horizontally across. Then Bradshaw would come out in a graph.

The carriage moves as if the vertical field of gravity g was disturbed by a field $\frac{F}{W}\,g$, or $\frac{B}{W}\,g$, parallel to the road. The direction of apparent gravity inside the carriage will be given by a short plumb line, which sets itself at right angles everywhere to the line below A E F D of apparent level, or in the line at which a man must stand on the floor without strap-hanging, making in the figure:

$$\frac{E\,B}{B\,A} = \frac{F}{W}, \frac{F\,C}{C\,D} = \frac{B}{W}.$$

The effect of this change in apparent gravity is very perceptible on the tube railway, to a passenger walking along the car, entering or leaving by the door at the front or rear end, as the train is starting or stopping. The jerk he feels at a stop is due chiefly to the sudden change to the normal vertical, and partly to the recovery of the carriage body on the springs; this is the after effect just before the complete stand still, *Parrêt complet*.

The effect is very pronounced also on the top of the motor bus, according as the driver puts in the clutch, or puts on the break, in causing the carriage body to pitch, making progress difficult on it for a passenger.

The calculation of the motion of the carriage body on the springs is a matter for subsequent theory, after the notion of moment of inertia and rotational motion has been introduced.

9. We have postulated (illogically) the kinematical theorems of a body falling freely under gravity, in saying that $\frac{v}{g}$ is the number of seconds of fall to acquire velocity v from rest; but this is included in (D), when $F = W$, $a = g$:

$$g = \frac{v}{t}, \quad t = \frac{v}{g};$$

and g is constant, as enunciated by Galileo in "de motu gravium naturaliter accelerato."

Then working with (C) the average velocity principle:

$$\frac{s}{t} = \frac{1}{2}\,v, \quad s = \frac{1}{2}\,v\,t = \frac{1}{2}\,g\,t^2, \text{ or } \frac{v^2}{2g},$$

the depth s vertical to fall to acquire velocity v from rest in t seconds.

Galileo used his pendulum, plummet on a thread, to prove mechanically that g is independent of material and weight, and disproved by it the theory, falsely attributed to Aristotle, that double weight would fall double as fast, making g proportional to W. And by altering the length of his pendulum in beating out equal intervals of time, he could verify the kinematical theorems, letting a ball or cylinder roll down a desk at the same time. Here is a detail worth developing in Mach's stimulating historic lectures on the "Science of Mathematics." And it is time the Aristotle-Galileo controversy should be settled by an appeal to authority. In making his statement Aristotle was really discussing the terminal velocity of a body falling in a resisting medium, where some such law is found to hold, as in bomb dropping, where the heavy body certainly comes down the faster, not merely

Fig.2.

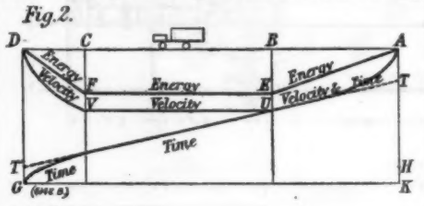
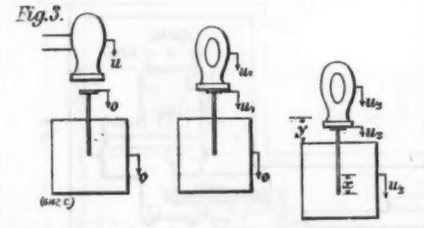


Fig.3.



of Galileo's little 1-lb and 2-lb weights, dropped about 100 ft. Any one can verify this for himself in Aristotle's *Physica* or *de cœlo*.

Instead of letting the body drop from rest, suppose it is falling already with velocity u, f/s, and has acquired velocity v after t seconds:

$$g = \frac{v-u}{t}, \quad t = \frac{v-u}{g},$$

$$\frac{s}{t} = \tfrac{1}{2}(v+u) = \frac{v^2-u^2}{2\,g\,t}, \quad s = \frac{v^2-u^2}{2g}.$$

So also the gain of energy, $W\,\frac{v^2-u^2}{2g}$, composed of the factors $W\,\frac{v-u}{g}$ and $\frac{1}{2}(v+u)$, is seen to be the work done by the impulse $W\,\frac{v-u}{g}$ multiplied by the mean average velocity $\frac{1}{2}(v+u)$, true also for a blow however short the duration.

In a different notation, if the velocity grows from $V - \frac{1}{2}U$ to $V + \frac{1}{2}U$, to split the difference, passing through a mean velocity V, the equations (A), (B) can be rewritten:

$$P\,t = W\,\frac{U}{g}, \quad P\,s = W\,\frac{U\,V}{g},$$

and the factor $\frac{1}{2}$ has disappeared.

Here is theory enough to serve the novice in dynamics, for six months or a year according to ability; and it will give him a definite grasp of the laws of motion if practised on concrete tangible applications, which in Kelvin's opinion should be chiefly numerical and on a large scale, as seen around him, such as I have collected in my "Notes on Dynamics" (Stationery Office). He should begin by taking a formula for granted, as from an engineer's pocket book, and test it on numerical applications until he has gained confidence in the application; after that he can examine the theory of the formula.

But avoid the explanation of a difficulty before it has arisen in the mind of the learner, suggesting difficulty instead of keeping it out of sight as long as possible. "We advance by ignoring our own ignorance, not by concentrating on assumed knowledge."—E. B. Wilson.

So if the teacher is a disciple of the doctrine of the non-Newtonian dynamics of Relativity, he had better keep it dark from the beginner, and not strew the primrose path with boulders and obstacles at the outset. Although it is needful for the teacher to have some critical acquaintance with these mysteries, as well as of non-Euclidean geometry, and of the metaphysics, too, of the multiplication table, they are best removed out of sight of the child learner, too young to understand why twice two is four, and how it is proved.

Some unbelievers have gone so far as to stigmatise the geometry which is not Euclidean as—"une grimace scientifique, paradoxe sans utilité, base volontairement fausse, plaisanterie logique," and so on.

10. To answer again the workman's question of the static pressure of a blow, his attention should be directed to the smith, forging red-hot iron on an anvil, and to noting how the compression at each blow diminishes as the iron cools, and the hammer seems to strike harder.

If the hammer, weighing W lb, strikes with velocity v, and compresses the iron a distance x, ft, the average static force F is given by the energy equation:

$$F\,x = W\,\frac{v^2}{2g}, \quad F = W\,\frac{v^2}{2\,gx}, \text{ lb}.$$

It is not easy to measure t the time of the blow, but it can be inferred from the momentum equation

$$F\,t = W\,\frac{v}{g}, \quad t = \frac{W}{F}\,\frac{v}{g} = \frac{x}{\frac{1}{2}v},$$

on the average velocity principle.

The anvil is here supposed large enough to take the blow of the hammer without flinching, as forming part of the solid earth.

The blow of a hammer on hot iron could be studied on a large scale formerly in the manufacture of the old muzzle-loading chubby Woolwich infant, a gun made of a steel tube strengthened by a jacket of wrought-iron coil. When first removed from the furnace, the compression of the red hot coil made by the first few blows of the steam-hammer was considerable, and the blow appeared soft; but as the iron cooled, the compression became smaller and the blow harder, or more violent in shaking the earth.

If the anvil is free to recoil, we come to the hammer-nail-block problem, as in holding-up in riveting.

Take a hammer weighing W lb, and strike a nail weighing w lb with velocity u f/s, to drive it into a block weighing M lb, free to recoil (Fig. 3); the resistance to penetration of the nail is assumed to require a static force of F lb to overcome it; to calculate the penetration x at each blow, and the time t of movement of the nail.

There are three stages in the operation:—

(1) The hammer is approaching the nail with velocity u; the nail and block are stationary.

(2) The hammer strikes the nail, and taking the impact as inelastic, hammer and nail start to move together with the same velocity u_1, such that

$$(W+w)\,\frac{u_1}{g} = W\,\frac{u}{g}.$$

(3) The nail penetrates the block against the resistance F lb, a distance x in time t, until hammer, nail and block are moving together with the same velocity u_2. Then, on the momentum principle,

$$(M+W+w)\,\frac{u_2}{g} = (W+w)\,\frac{u_1}{g} = W\,\frac{u}{g},$$

$$F = M\,\frac{u_2}{g} = (W+w)\,\frac{u_1-u_2}{g} = \frac{M\,W}{M+W+w}\,\frac{u}{g}.$$

On the principle of energy,

$F\,x =$ work used up in penetration

$$= (W+w)\,\frac{u_1^2}{2g} - (M+W+w)\,\frac{u_2^2}{2g}$$

$$= \frac{M\,W^2}{(W+w)(M+W+w)}\,\frac{u^2}{2g};$$

and t, x are thence determined.

Working on the average velocity principle, the velocity of the nail through the block changes from u_1 to 0, so that

$$x = \frac{1}{2} u_1 t = \frac{1}{2} \frac{W u}{W + w} \cdot \frac{M W}{M + W + w}, \frac{u}{g},$$

as before.

And the block will have advanced a distance y during the penetration with average velocity $\frac{1}{2} u_2$ for a time t, so that

$$y = \frac{1}{2} u_2 t = \frac{M W^2}{(M + W + w)^2} \frac{v^2}{2 g F}.$$

(4) Finally, all three, hammer, nail and block, are moving together with common velocity u_2, until brought up by some other action.

Similar theory is required in the action of the crusher gauge, where the compression of a cylinder of soft copper is measured to give a record of the pressure exerted by a piston hammer, driven by the powder gas.

Then there is the sap helmet and Dowe cuirass, where the blow of a light bullet moving at high velocity is mitigated by the extra weight of the helmet, so that it can be received without harm on the head or body, provided the bullet is shattered or deflected, and the metal is thick enough to resist penetration. The modern steel helmet is another application. And the operation of firing the bullet out of a rifle from the shoulder is only the same dynamical action in reverse order.

The same principle of momentum will serve to determine the steady static thrust due to the impact of a stream of bodies, such as a jet of water, or the links of a chain falling vertically on the ground, to be represented in a graphical construction.

Bertram Hopkinson measured the time of impact of a bullet, by receiving it on a steel cylindrical rod suspended as a ballistic pendulum, the bullet being supposed to act as if fluid, and to crush up and escape sideways, so that the impact lasts as long as the bullet moves its own length, ; this is described later, in § 19, under the ballistic pendulum.

11. The coal train problem. Before the introduction of the continuous air break, the driver kept control of a long train of coal trucks, with inelastic buffers and slack chains, by the succession of bumps between the buffers or jerks of the chain coupling.

Call W, tons, the weight of engine and tender, w of each truck, and F the tractive force in tons at the bite of the driving wheels with the rail. Starting with all the buffers in contact, call V the velocity just before the rth jerk, and U_r just after; then

$$(W + r - 1 . w) \frac{V}{g} = (W + r w) \frac{U_r}{g}, \text{ sec-ton};$$

and a, ft, denoting the buffer interval when the chain is taut,

$$F a = (W + r - 1 . w) \frac{V_r^2 - U_{r-1}^2}{2 g}, \text{ ft-ton.}$$

Eliminating the V's,

$$(W + r - 1.w) F a = (W + r w)^2 \frac{U_r^2}{2g} - (W + r - 1.w)^2 \frac{U_{r-1}^2}{2g},$$

a sequence equation, from which by successive addition, from $U_0 = 0$,

$$(r W + \tfrac{1}{2} r . r - 1 . w) F a = (W + r w)^2 \frac{U_r^2}{2g},$$

thus determining U_r, the velocity with which the rth truck starts off.

The engine will have advanced $r a$ feet, and the jerks being instantaneous and inelastic, the momentum principle gives the time t to the rth jerk by

$$F t = \text{momentum generated} = (W + r w) \frac{U_r}{g},$$

and thence

$$t = \sqrt{\left(\frac{r W + \frac{1}{2} r . r - 1 . w}{F}\right)} \sqrt{\frac{2a}{g}}, \text{ seconds.}$$

The work done by the engine is $F r a$, ft-ton, and the energy acquired being

$$(W + r w) \frac{U_r^2}{2g} = \frac{r W + \frac{1}{2} r . r - 1.w}{W + r w} F a, \text{ ft-ton,}$$

the energy dissipated by the jerks is the fraction

$$1 - \frac{W + \frac{1}{2} r - 1 . w}{W + r w} = \frac{\frac{1}{2} (r + 1) W}{W + r w}$$

of the work done $F r a$, ft-ton.

It steam was shut off at the first jerk,

$$(W + r w) U_r = W V_1,$$

and t_r denoting the time from the start to the rth jerk,

$$t_r - t_{r-1} = \frac{a}{U_r} = \left(1 + \frac{r w}{W}\right) \frac{a}{V_1} = \left(1 + \frac{r w}{W}\right) t_1$$

$$t_r = \left(r + \frac{\frac{1}{2} r . r - 1 . w}{W}\right) t_1 .$$

When the train is at full extent, and steam is shut off and breaks applied, calling up a resistance B, tons, on engine and tender, a reverse operation takes place: a series of bumps is heard between the buffers, and speed is reduced rapidly. In this way the driver had control of a long train of coal trucks, before the continuous air break was in use.

12. It was formerly a piece of logical persecution in dynamics to start the beginner on a number of pitfalls and entanglements, called "change of units," supposed a wholesome discipline for him before he started on realities he had seen.

But there has been no need for us, so far, to use any other units than our Imperial measures of the foot, and lb or ton, with an occasional appeal to the metric equivalents of the metre and kilogramme, (m and kg).

We do not try to trip up the novice at the outset with such questions, formerly considered educative, as: "In the equations $W = M g$, $M = \rho V$, $W = s V$, given the unit of mass is one hundred weight, the unit of weight is the weight of one hundredweight,

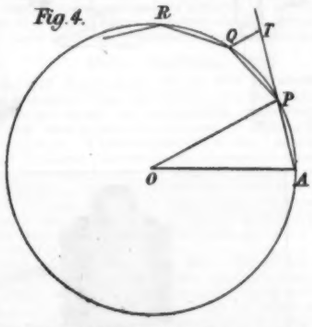


Fig. 4.

the standard substance is water, . . ." to be found in Parkinson and Todhunter's Mechanics, or Besant's Hydrostatics, there copied from their precursors.

The all pervasive g we have taken in round numbers at 32, f/s², which in the Metric System is recognised as 9·81, m/s².

The second is always taken as unit of time in dynamical calculation, chiefly because it keeps g within moderate size; but the second is too minute to observe with accuracy in an engineering measurement, where it is usually replaced by the minute; revolutions are always reckoned by the number in one minute, as 20,000 in the gyro-compass.

Minute and second are the Latin "minutos" and "secundos" (minutos), fractions of the hour, successive 60th parts, in accordance with the subdivision of the Chaldæan astronomer.

All clocks, watches, and chronometers are graduated in sexagesimal time, and they were too valuable and plentiful to throw away, in favour of the centesimal divisions of the Metric System.

With the minute as unit of time, g requires to be multiplied by 60 twice over, and would be 115,200 foot-minute units, f/m².

Newton had verified the Law of Gravitation as far as to the moon, when he pointed out that g up at the moon was 32, in foot-minute units; so that the moon was drawn towards the earth 16 feet from the tangent every minute, the moon being at a distance 60 times the earth's radius.

But this was not till after he had discovered his error in taking the soldier's land mile as the same as the nautical geographical mile, as he had been taught.

13. In the treatment of the Principia, the effect of a continuous force in changing the momentum of the body is replaced by a series of discrete blows, supposed to act at short intervals of time. The effect of supposing these intervals to be of a finite unlimited magnitude was investigated in ENGINEERING, October 11, 1918, page 393.

In the simplest case of a circular orbit, as of the moon round the earth, treated in this manner as an equilateral polygon described under a series of equal timed blows to the centre O, the straight line path A P T . . . described with uniform velocity V is supposed changed into the broken equilateral polygonal path A P Q R . . . of equal chords, inscribed in a circle of radius a, and described in equal time t, as if rebounding from the interior of the circle, where

A P = P T = P Q = V t, and T Q = U t is parallel to O P, U being the velocity communicated by the blow to O. (Fig. 4).

Then in the similar triangles O A P, P T Q,

$$\frac{TQ}{PT} = \frac{AP}{OA}, \quad Ut = TQ = \frac{AP^2}{OA} = \frac{V^2}{a} t^2, \quad \frac{U}{t} = \frac{V^2}{a} = \frac{4\pi^2 a}{T^2},$$

for a periodic time T, and U/t measures the average acceleration to generate the velocity U continuously in the time t.

In the case of the Moon, taking t one minute, T Q = 16 ft, the distance described with average velocity $\frac{1}{2}$ U in one minnte; and the acceleration of the earth's gravity up at the moon is 32, f/m², in agreement with the Law of Gravitation, inversely as the square of the distance.

If the velocity of the moon was turned up away from the earth, the moon would reach to a point B, where A B = O A, on the inverse square law of attraction.

From B the moon would fall plumb on the earth at O, in the time of half a lunation, by Kepler's Law III; the attenuated rectilinear orbit B O having the same major axis as the diameter of the orbit of the moon.

The case of parabolic motion of a ball thrown in the air was considered in the same way, in ENGINEERING, p. 394, October 11, 1918.

(To be continued.)

PROTECTION FROM CARBON MONOXIDE.—The poisonous and insiduous character of carbon monoxide CO is well known. During the war many soldiers were killed by the evolution of CO, not from poison-gas shells, but from defective explosive shells which had failed to explode. The CO is the most dangerous gas of the aftermath of methane explosion in mines, and cases of CO poisoning have occurred in automobile garages, during gun practice, in gas works, in iron and steel works, and near leaky flues. During the war Arthur B. Lamb, W. C. Bray, and J. C. W. Frazer, of the United States Bureau of Mines, found in "hopcalite" an effective absorbent for CO; the research, begun in the University of California, was continued at Washington and elsewhere, and publication was recently permitted. Hopcalite consists of a mixture of about 50 per cent. of manganese dioxide, 30 per cent. of copper oxide, 15 per cent. of cobalt dioxide, and 5 per cent. of silver oxide. The mixture is placed in ordinary gas-mask canisters, in which it gradually loses its efficacy by the absorption of moisture; this absorption can to a certain extent be determined by control of the weight of the canister, an increase in weight indicating water absorption. Experiments are to be made in the projected tunnel under the Hudson, between New York and Jersey City. Dangers from the heavy automobile traffic are feared for this tunnel, and 13 students from Yale University have offered themselves for the risky experimenting on the amount of CO that man may safely be exposed to.

EFFECTS OF STRAIN AND OF HEAT TREATMENT ON METAL STRUCTURE.—The more or less slow changes in crystalline structure which take place in metals after cold work and after annealing can, according to S. Nishikawa and G. Asahara, be followed by means of X-ray examination. They apply (*Physical Review*, January, 1920, pages 38 to 45) the original method of Laue, by letting a pencil of the rays, 3 mm. in diameter, fall normally on the rolled sheet of metal (from 0·1 mm. to 0·54 mm. in thickness); the sheet is fixed about 5 cm. from the photographic plate on which spots grouped in characteristic patterns are produced. Rolled aluminium, cadmium, copper, zinc and brass gave ill-defined patterns, but a symmetry with respect to the direction of rolling was noticeable. Silver and tin showed similar patterns immediately after rolling; when the specimens were kept at ordinary temperature for a week or two, the patterns changed into those characteristic of the annealed metals. In the case of lead and thallium no symmetry was visible after rolling, indicating either that the rolling did not distort the structure or that the crystalline recovery is rapid. The annealing was effected in an electric furnace at temperatures up to 800 deg. C. The metals, of course, differed greatly in their response to annealing In the case of silver and tin annealing for 30 minutes at 80 deg. sufficed to obliterate all traces of the previous cold work; for copper, 2 hours at 800 deg. was insufficient. Thallium annealed at various temperatures from 100 deg. up to 250 deg. indicated the existence of a transformation point at 217 deg. C., which would agree with observations by other methods; in tin, however, the X-ray examination did not reveal any transformation near 160 deg.

OXY-ACETYLENE MANHOLE CUTTING MACHINE.

CONSTRUCTED BY THE DAVIS-BOURNONVILLE COMPANY, JERSEY CITY, N.J., U.S.A.

Fig. 1.

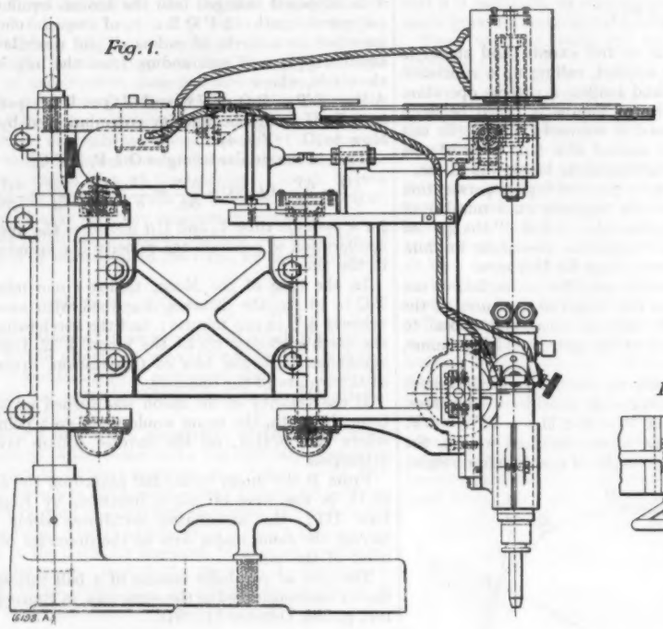


Fig. 2.

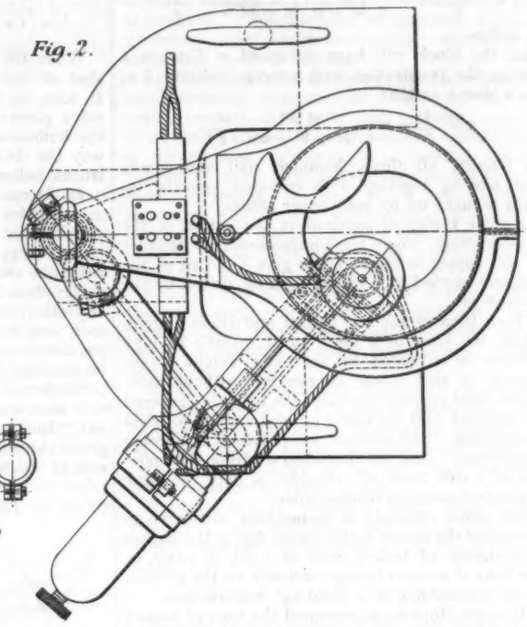
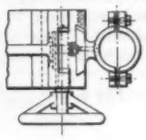


Fig. 3.



AN interesting application in automatic cutting by the oxy-acetylene process is exemplified in the illustrations Figs. 1 to 4, annexed. The appliance illustrated is intended for the repetition cutting of manholes to template. It is made by the Davis-Bournonville Company, Jersey City, N.J., U.S.A., and has been styled by them the Camograph No. 2. The firm some time ago produced a machine with a tracing wheel, by means of which the torch could be made to follow a blue print. In the present machine the action is automatic, the torch following a cam or template.

A heavy cast-iron base of U-shape is provided, at the back of which is a vertical post. On this post is pivoted a double-jointed arm consisting of two leaves. These are light but rigid aluminium castings, and are mounted on ball bearings, which are also used for the hinge joint between them. The cutting torch is mounted pointing vertically downwards, on the lower outer end of this double-jointed arm, as will be clear from the photograph reproduced. The automatic movement or feed is obtained by the gear at the top of the machine. Fastened to the post is a large frame or holder in which is a circular opening. In this opening can be fixed cam plates cut to the form of the manhole it is desired to cut in the work. On the top of the outer leaf of the double-jointed arm is a small motor, driving a spindle, which, by worm and double-reduction gears, drives a small feed roller mounted exactly on the axis of the torch. This feed roller is in contact with the cam face, and therefore guides the torch along the required path. The feed is actually obtained by friction, the necessary adhesion of the roller on the cam face being obtained by a powerful electro-magnet, which is shown above the cam plate holder. This magnetises the feed roller, and it is drawn towards the cam face, against which it rotates. Direct current is required. The control is by a double push button switch for starting and stopping the motor, and for energising the magnet. Speed control is affected by means of a small knurled screw on the end of the motor casing. The electric control is connected up with the oxygen valve so that when the oxygen supply is turned on for cutting the feed motion starts.

This machine was originally designed for cutting hand holes, &c., in ship and boiler plates. It has immense advantages over the drilling machine, for it can be placed in any position on a large plate which would otherwise involve the use either of a large machine tool, or a portable tool with necessary preliminary drilling. In addition, of course, the finish obtained with the torch is so much better than that with a series of drilled holes, as frequently to require no subsequent dressing up. Very little power is required to drive the machine, which is designed to cut openings of about 7 in., though holes with one dimension considerably larger than that may be cut. A hand hole having a periphery of 12 in. to 13 in. can be cut in $\frac{1}{4}$ in. to $\frac{5}{8}$ in. steel in about a minute. All ordinary thickness of boiler plate may be cut. The shape of the hole is dependent upon the cam. The cam plate can be replaced by another practically without loss of time. Care must be taken when perforating and cutting plates in this manner, to perforate well inside the finishing line, in order to obtain a clean contour finish. A secondary cam is provided to guide the feed roller after perforating up to the main cam face.

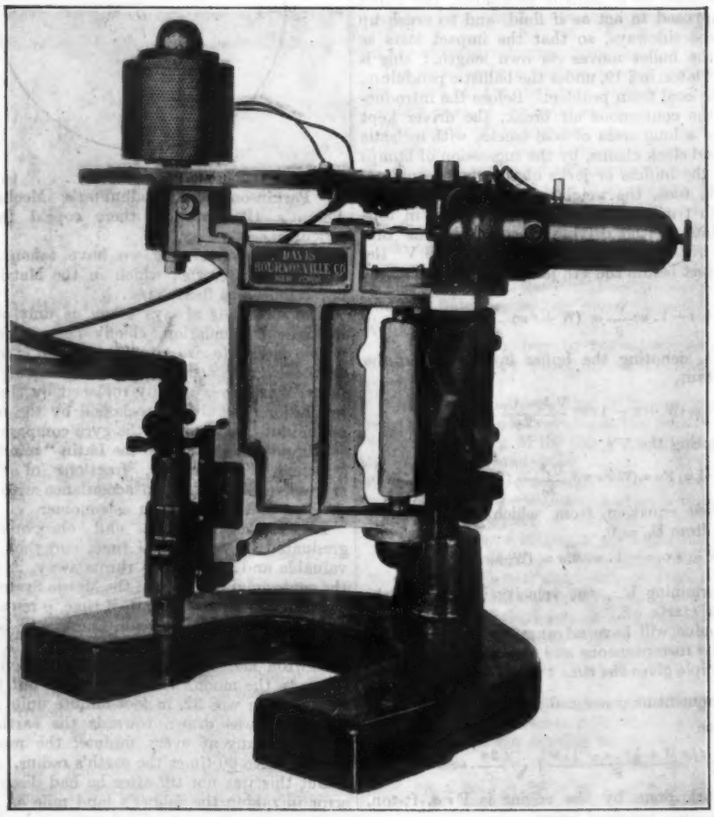


FIG. 4.

The machine weighs 125 lb. It is provided with an eyebolt at the top of the pillar, so that it is easily slung. It is about 25 in. high and 17 in. wide. The motor and magnet require a supply of direct electric current at 110 volts.

THE VALUATION OF ORES AND IRON-MAKING MATERIAL*.

By C. H. RIDSDALE, F.I.C., F.C.S., Middlesbrough.

THERE is perhaps no more striking instance of the need for chemical guidance than in buying and selling ores. About 10,000,000 tons of pig-iron are made in this country in a normal year, involving the use of 20,000,000 tons to 30,000,000 tons of ironstone and ore of many kinds, and purchased at widely different prices; the final decision as to which shall be bought, and the relative price to be paid being, in most cases, in the hands of men who are not familiar with the chemical reactions attendant on its reduction, or the practical considerations which can be learnt only by long experience in the responsible running of blast furnaces. This duty has been allocated to them not on account of their knowledge of these vital matters, but for reasons of office organisation or because of their bargaining power, and they have no really sound scientific system on which to work. Yet a misjudgment of only 6*d.* or 1*s.* per ton on 500,000 tons of ore—a by no means uncommon quantity for one firm to buy in a year, especially now there are so many amalgamations—involves no less than 12,500*l.* to 25,000*l.* Very great trouble is taken and considerable sums are spent in looking into the merits of a piece of machinery or plant which will save only a fraction of this sum. How much time or money are spent over careful investigations as to the real value of an ore? Frequently neither the chemist nor the blast-furnace manager have been adequately consulted, or have had any opportunity of closely investigating the matter.

Another reason for bringing forward this subject at the present time is that the considerations involved bear largely on the question of fuel economy, of which so much has been heard lately. Even when coke was only 15*s.* a ton an excessive consumption of it rendered the use of certain ores uneconomical. How much more important this is with fuel as scarce as it is, and coke at its present price.

Before proceeding further, however, it should be recognised clearly that price may be no gauge of value, and the mere getting of a reduction below the price asked may not necessarily imply that a good bargain has been made. It may be bad business to buy a poor ore even at a very low price, and good business to buy a better ore at what appears to be a very high price. Price is to a large extent artificial and arbitrary, and governed not only by the value of the article, but by other considerations. The price, however, though it may be more, will not for any length of time be less than the cost of winning (mining, royalty, &c.) plus transport, merchant's and other charges, and a small profit; and although certain lots may be disposed of for a short time, or through special circumstances (such as to create a demand) below this, they manifestly cannot continue so to be sold on a large scale for long. Cost, to the iron-maker, is the total sum paid per ton of ore which is actually smelted in the blast furnace. Any ore which after being weighed does not reach it through being blown away whilst unloading, or loading, or washed away by rain, or blown out of the furnaces into the dust-catchers, or whilst lowering the bell—has cost just as much per ton as the ore smelted, but has yielded nothing. Value is what the ore is really worth to the iron-maker. Unless it is above the total cost to him, it is bad business to use it. As the value depends on a great deal more than the iron contents, in fact, upon everything that is involved in working it, a manager or other buyer who constantly has to choose between materials, the prices of which may differ considerably from their real or intrinsic values, cannot act to the fullest advantage unless he knows these with exactitude. A few pence may mean all the difference between profit and loss. Often the materials are new to him, and he has nothing to guide him. In a great many cases, however, past experience of a material enables him to buy so as to yield a profit, although with more exact data he might have bought to still better advantage.

Although practical experience, if it be available and reliable, is the best, in fact, the final test, and is, irrespective of all theory, the real issue, this is far less easily obtainable than may be supposed, for any particular ore is seldom used alone, and trials made under carefully watched conditions (by which only can true effects be accurately gauged) are the exception, so the conclusions formed may not be reliable, but masked, or affected by unobserved conditions. Generally a cargo is spread over two or three furnaces, and mixed with other ores; also the conditions of working may not be normal during the trial. On the other hand, there are certain scientific data—chemical and thermal—which have been carefully determined, and the question is: Cannot a more accurate valuation be made from a full analysis and statement of the mechanical condition coupled with practical experience, than from the ordinary trials not conducted on strictly scientific lines, or of which the records are incomplete, and the true effects not correctly differentiated? Very little appears to have been done hitherto—or at any rate published—to utilise these data, combined with practice, for valuation. Yet such determinations should (unless possibly with rare exceptions) prove by far the most reliable means of valuation.

Amongst the means for checking which the author has had may be mentioned, not only analyses of the ores used, yields obtained, and other usual blast-furnace records, but analyses not merely occasional, but extending over many years, and for every ladle of slag and every cast of iron produced, in conjunction with observations of their fracture.

It is impracticable within the limits of a short paper to do more than set forth briefly the case for proper valuation. This is done not dogmatically, but with the hope of eliciting discussion by practical blast-furnace men who have studied the chemical and thermal sides of the problem. It is unfortunately only possible to give a few examples of the heat balance sheets and other detailed working involved. What we are concerned to know with reference to an ore to be valued, is how it will compare on exactly the same basis and conditions with some other, which thus becomes a standard. The value determined is, of course, relative, not absolute. Each ore naturally tends to be best suited for iron of a particular type, although it may be practicable to use it for another type, and for whatever type is taken as a standard there will, with normal furnace working, be one best type and basicity of slag. When compared on these lines, it will be found that as the valuation is relative, a good many details in a particular practice may differ from those of the standard taken without invalidating the comparison, as it is taken for both.

Analysis.—The first essential is a full analysis of the ore expressed, so as to show not only how the 100 per cent is made up, but also its constitution—that is, the condition in which the iron and manganese exist, and also the impurities with the nature of the gangue. For instance, it is necessary to ascertain whether the silica is present as quartz or shale, and in any event the pure silica, not merely the insoluble siliceous matter, should be shown. It should show whether the lime is present as carbonate or silicate; whether the sulphur is present as calcium or barium sulphate, or as pyrites. If such an analysis be not available, the valuer must build up one from his experience and from such data as he can command. There is greater need, too, for uniformity of expression of analyses by different chemists, and adapting them to show more readily what the person using them wants to know. (Examples are given in table form of an arrangement which the author introduced many years ago as convenient to iron-makers, showing at a glance approximately the pig, gas and slag formers (acid and basic), respectively, grouped together.)

METAL PRODUCED.

Quality and Quantity of Ore per Ton "Natural Pig" made to Standard Type and Grade.—As the value of the ore is affected by all that is involved in turning it into iron, this is best gauged by the cost of making a ton of pig-iron from it. The composition of the "natural pig" it would produce (theoretically) if smelted alone must therefore be worked out. To find correctly the quantity of ore, limestone, coke, &c., it will take to do this we must first note from the dominant constituent—as phosphorus, manganese, &c.—what type of pig-iron it is best adapted to make, and then decide on the grade, so that it may be valued on this basis.

In each of four examples given there are certain constituents—carbon, silicon and sulphur—the percentage of which depends on the furnace working rather than on the ore, and for comparison they are taken as being constant, whilst the phosphorus and arsenic vary directly with the ore content of those elements, and the manganese varies primarily according to the ore and, secondarily, according to the furnace working and the basicity of the slag. The percentage of these bodies present in the pig-iron varies, therefore, for its type and grade, which must be known before the iron in the pig-iron and ore per ton of pig-iron, can be determined. This may seem rather unnecessarily troublesome, but for the valuation to be accurate it must be more exact than in some of the rough methods employed, which may be 2 per cent. or 3 per cent. out.

Slag.—A given type and grade of pig iron to be made presupposes a certain basicity of the slag necessary for its proper manufacture, and this must be borne in mind when calculating the manganese which would enter the pig-iron. This and the phosphorus and arsenic having been determined, in the absence of other metals as chromium, nickel, copper, &c., the difference can be taken as iron. The basicity of the slag, in conjunction, of course, with the temperature of the hearth, affects the working of the furnace vitally, not only as regards the amount of manganese, silicon, and sulphur reduced, but also as regards coke consumption. It is therefore very necessary that when ores are compared for the same purpose it should be on the same basicity. If the standard ore is taken at, say, 1·5 base to 1 acid—generally expressed in terms of $\frac{CaO}{SiO_2}$ (but not to be taken too literally)—the ore to be valued must, *pari passu*, be taken at the same, or it is not a fair comparison, as, in working, the proper effect would not be obtained from the ore. In practice this point is not always observed, and the result is therefore misleading. For instance, an ironstone was being delivered simultaneously to a firm making foundry iron on a 1·6 basicity slag, and to another making basic with a 1·9 slag. A sudden large increase of silica was strongly complained of by the latter, their iron losing its manganese and gaining in sulphur, extra lime and coke having to be used. The mine-owners said these troubles could not be due to their stone, as the other firm had no trouble or irregular working, and had not used extra lime or coke. Investigation showed that their slag had run down to 1·3, and the iron had run up considerably in silicon. The lower iron content of the poor stone was equivalent to there being more coke per ton of pig-iron, but for want of close watching of yields and consumption this was not discovered at the time, and the lighter burden enabled the furnace to keep going under those conditions. The whole effect was therefore masked, and would have escaped notice—although the quality of the products was not normal—if the different practice and close watchfulness of the other firm had not called attention to it.

On the other hand, occasionally there may be some circumstances which necessitate the use of a different basicity—for instance, an excessive amount of sulphur in the ore to be valued, present in a form which readily passes into the iron when reduced, namely, in combination with iron as sulphur in the form of pyrites (FeS_2).

Another point about the basicity in actual working is the proportion of the different bases taken as equivalent to lime. Excessive alumina, for instance, makes a ropy, viscous slag, which retards free driving, whilst manganous oxide tends to make a thin cutting slag, and to a considerable extent to counteract the effect of alumina. Magnesia again has not quite the same effect as lime. These points illustrate the futility of expecting that valuation can be reduced to a mere question of mathematics carried out by the clerical staff.

Lime or Limestone required per Ton of Ore and Pig-iron.—This must be calculated, and depends on definite chemical principles. It is a matter which is fairly well understood, although some methods in use are of doubtful reliability. The author prefers, as ore mixtures generally require the addition of some extra base, to estimate the effect of each base present in terms of silica, fluxed at the standard rate of basicity of the slag, for the particular type of pig to be made. This gives a percentage of silica fluxed by the bases of the ore itself (if any), which deducted from the percentage of silica present leaves the excess or "free" silica to be fluxed by lime (expressed in terms of limestone, for standard purposes) from outside sources. Should bases in the ore be in excess of the requirements for silica, the equivalent deficiency of silica is expressed as "limestone substituted," and this and any coke not burnt by CO_2 of limestone should in consequence be credited. The figure per ton of ore, multiplied by the ore per ton of pig, gives the limestone per ton of pig. Of course limestone can be calculated, if desired, to the half, two-thirds, or completely burnt state.

Coke required per Ton of Pig-iron and Ore.—Ascertaining this is not so simple as calculating the limestone required. Such attempts as the author has seen have generally shown little more than the carbon for chemical requirements, and have not been satisfactory. It is necessary first, in order to gauge the behaviour of each individual constituent, to prepare a "balance-sheet" of it, showing all the carbon required and the heat developed or absorbed on its account. For a comparison of ores, good normal conditions of furnace working are assumed for the reactions that take place. Reduction is regarded as being effected, for ferric oxide (free), in a reasonably porous condition, by carbon monoxide in the upper part of the blast-furnace, with consequent economy due to obtaining the 70 per cent. extra heat out of each unit of carbon; but for practically everything else—(even ferric oxide if in a vitreous state or otherwise held in combination which prevents this), ferrous oxide (whether as carbonate, silicate, or other combination), magnetic oxide, manganous oxide, manganese dioxide, mangano-manganic oxide, phosphoric acid, silica, &c.—in the lower part of the furnace, or the hearth, reduction is effected by solid carbon. The author is satisfied that, for practical purposes, this is what occurs.

Carbonic Acid, whether from incompletely calcined ironstone, or from limestone, is taken as being driven off at such a temperature as allows it to dissolve an extra unit of carbon. Very few furnaces have such low temperature or rate of driving that this does not occur, though, of course, in cases where it is known that it does not, this item need not be charged. Whether all driven off or not, it does not appreciably alter the relative value of ores if the quantities are about equal. Special attention should, however, be called to the further bad effect with incompletely calcined ferrous carbonates, due to the resultant ferrous oxide having to be reduced by solid carbon.

Moisture and Combined Water, entering the top of the furnace, are taken as being simply driven off by the sensible heat of the gases. Whilst they may keep the furnace top cool, they also tend to make the gases burn badly. Of course, if the gases are washed before burning this does not apply. If the moisture exists so that it is expelled slowly and with difficulty, and so gets low down in the furnace, as, for instance, when contained in large lumps which descend before it is all driven off; or if it enters the lower part of the furnace, as from leaky tuyeres or blocks, or in the blast, it is reduced by solid carbon, forming CO and H.

(The paper then gave five different "balance-sheets")

In one example stated, the requirements of coke per ton, both for the metal if from pure peroxide and the extras for impurities, &c., are obtained in two portions: (1) The net quantity required thermally (based on the heat units) and chemically for each reaction to be carried out under theoretical (perfect) conditions, viz., from pure peroxide. (2) The "extras," or further quantity required for losses inseparable from the carrying out of those reactions under ordinary (imperfect) conditions met with in practice, and including the impurities.

A point that is perhaps not sufficiently realised, specially with regard to ores that need to be worked with highly basic slags, such as when making ferro-manganese and manganiferous irons (as, for instance, basic Bessemer, which demands slags and furnace working similar in many respects, and in which it is probably quite as difficult, in view of silicates used, to retain the manganese), is that, apart from limestone required for the ore, the coke ash, which contains a good deal of silica, must also be allowed for, especially as the poorer and more siliceous an ore is the more coke it will require. Extra limestone will be required for the coke, and extra coke for the extra limestone and the extra slag produced, and so on to infinity; though after the first two stages it becomes negligible. These items for "self" or "inter" satisfaction are therefore included. Another item is a combined allowance as derived from practice for tuyere water, water of the blast (the calculations so far having been based on dry air), water of the

* Abstract of a paper read before the Iron and Steel Institute on May 6.

coke, and losses by transmission through the walls and by means of slag and iron run out; and as all these are directly dependent on the amount of coke used, this item is taken as a percentage on the coke required apart from it. The total amount taken is 19 per cent. of the other requirements, including that for self-satisfaction (or 17·82 per cent. apart from this) which is shown separately so as to allow for showing the limestone and slag for this variable quantity.

Having now got for any standard type and grade of pig-iron the quantity of materials required to make 1 ton, and the slag, &c., produced under normal conditions, it is easy to calculate the cost (so far as it is expressed by these, and without having allowed for any abnormal features) at current prices as compared with the same for any other ore taken as a standard. This will give the relative costs for them delivered at the works, but as the real cost for materials depends not only on this, or even on the costs as charged, but as actually retained in and smelted by the furnace, there are several points frequently overlooked which should always be borne in mind, as they may very much affect the real value; for instance: *Ore.*—Whether it is delivered in such a way that it can be tipped straight into bins, bunker kilns, &c., without further handling, or has usually, all or most of it, to be unloaded into stock, with not only the cost of this, but the loss, if it contains fine dust, by wind and rain. Also it may have to be carried farther from the point of arrival or stocking to the furnaces. Such occurrences may apply particularly as between ores delivered at a wharf, and a local stone or ore delivered direct in trucks. *Materials to Handle or Dispose of (Weight and Volume).*—The relative quantity must be considered not of the ore alone, but also of limestone and coke used, and slag and gases produced. The latter having considerable commercial value must be considered, and whether they are specially dry or wet, dusty, &c. *Blast.*—This, of course, has an appreciable cost, and depends on the quantity of coke to be burnt by it. *Output.*—Does not depend simply upon the richness of the ore in iron or other pig-iron formers, or conversely upon the lowness of the earthy matters to be introduced and slag made per ton, but also upon the state of combination of its constituents, its refractoriness, mechanical and physical condition, and other points which require very careful consideration.

The calculated coke consumption to a large extent, though not entirely, is a gauge of these factors, and it is obvious with two ores of the same type, but one requiring 25 cwt. coke instead of 22 cwt., that the make would, with the same rate of blowing and other conditions, be less, as 25 cwt. coke would take proportionately longer to burn.

This affords another example of the difficulty of accurately judging a cargo of ore merely by a practical trial on a mixture of which it was only a small proportion, as its effect on the total make and coke consumption on a short period may be upset by so many contingencies. This no doubt frequently masks the true effect of ores, and emphasises the need for an independent scientific indication.

Without going into detail it is obvious that an ore which, from its combined effects, would increase a make from 1,000 tons to 1,200 tons per furnace (or proportionally), would on all the fixed and other charges affected have a decided extra value per ton on this account; besides the increased turnover in a given time, and—as in many cases, for instance, where furnaces serve a steelworks—further value is gained beyond that realised directly at the furnaces.

MECHANICAL AND PHYSICAL CONDITION.

It is perhaps not wide of the mark to say that the physical and mechanical condition of the ore often has as important an influence on the value as its chemical composition within the usual range.

Dust.—The loss of ore through this whilst loading and unloading has been already referred to, and it is also very objectionable if charged into the furnace. Much of it blows away when the bell is lowered, and into the dust catchers, whilst what remains in the furnace, especially, if finely granular, is liable to run through the interstices of the burden, like sand through an hour glass, and reach the hearth, to be reduced there by solid carbon, instead of in the upper part of the furnace by carbonic oxide, thus cooling the hearth and upsetting the quality. The accentuated effect of apparently trivial causes in chilling the hearth (the most sensitive part of the furnace) has already been explained by the author in a former discussion before this Institute,* and he had in mind one ore in particular, the formation of which was like an aggregation of homœpathic pillules, many of which ran rapidly down, and consequently in spite of everything tried it was impracticable to maintain iron of regular quality, the changes being extremely sudden. Again, dusty gases if burnt direct are objectionable, and are more expensive to clean. Accumulations of dust (in the more stagnant parts of the charge) tend likewise to choke the furnace, causing sticking or hanging, channelling and scaffolding. Apart, too, from the objection to dust itself, it is seldom spread evenly throughout the whole charge; or even if it is so at first, it will not remain so during working.

Friability.—Ores which crush readily, either as charged or after charging, may be classed practically as though they contained a large quantity of dust. In fact, before they reach the furnace they may crumble and lose appreciable weight whilst being handled. It must not be forgotten that the portion wasted costs just as much per ton as that used. There are not only soft ores, but also certain magnetic ores, consisting of aggregates of large crystals, individually hard, but loosely held together, which easily disintegrate by heat and pressure. Another objectionable type of ore coming under this category is that which on being rapidly heated decrepitates, much of it flying into small pieces. There are also ores, some of them hard as mined, rich in carbonate of lime, which not only become soft when calcined, but also slake on exposure to the air and rain, swelling, disintegrating and crumbling like the quicklime of which they contain a considerable proportion. There are likewise ores of the hydrated brown peroxide type which contain a large quantity of wet small—practically mud—which not only has a very damping effect on the furnace, but has caused explosions by slips bringing large wet masses suddenly into highly-heated zones several feet lower down.

Large Lumps.—The opposite extreme is also objectionable, especially if the ores are refractory, either through their chemical or physical nature. In these days of rapid drive they travel down the furnace quicker than the gases and heat can properly penetrate them, and so reach the hearth cooler inside than they ought to, and also imperfectly reduced; both causes chilling the hearth. For this reason certain dense magnetic ores in large lumps, even though rich in iron and of splendid composition so far as impurities are concerned, are not nearly so good to smelt as ores of the peroxide type, which are much inferior to them chemically in these respects. The open-hearth process is an economical means of reducing any such ores as regards fuel. The author has already described* trials he made on the use of ore of this type, in which, despite its richness, beyond a certain point the coke consumption became excessive and the make went down. It may be argued that large ores can be broken smaller, but many works have no provision for this, and where it is done by hand it is not always dependable. Besides, in either case, there is the cost of breaking and the dust made to consider. In actual practice, if ores are sent out large, a great many large lumps do find their way to the furnaces in spite of arrangements to the contrary.

"Rubble."—There is little doubt that this size, say from 1 in. to 5 ins. diameter, cube or equivalent, is the ideal size for most ores, and that both larger and smaller are less favourable; though, of course, the best size would vary somewhat with the size of the other materials, the character of the ores and their degree of refractoriness. The author has always wished to see what would be the effect on make, coke economy, and smooth driving with a furnace run entirely on such sized material of all kinds. He is under the impression that, provided the plant were suitably laid out to deal with materials received with the minimum of handling, and everything larger than 5 ins. was broken, or smaller than, say, ¼ in. briquetted or otherwise consolidated (without at the same time rendering it refractory), there would be benefits greatly outweighing the costs.

Physical Condition.—Peroxide ores sufficiently porous for the gases to penetrate and reduce readily are the best, whilst very hard, dense, non-porous or permeable ores, particularly vitreous materials, such as siliceous mill cinder, tap cinder, scar, &c., are not reduced till they reach the hearth and dissolve in the slag bath, the bases combining with the silica and the iron oxides being reduced by solid carbon. Such materials, particularly of the ferrous silicate class, are very liable to suffer a further loss, especially if the slag be not sufficiently basic, because, the moment the temperature of the hearth drops, a considerable proportion of the silicate passes unreduced out of the furnace, giving a black slag. In such conditions, with a burden containing tap cinder a good deal of phosphorus also passes out in the slag; whilst the green slags, as when making ferro-magnanese, spiegel, or other manganiferous iron, due to manganous silicate, are another example.

OTHER CHEMICAL FACTORS AFFECTING THE VALUE OF ORES.

A few indications may be given which generally hold good, but may in certain circumstances be modified. They illustrate also how the same ore may have several values, varying according to the type of iron for which it is used.

Phosphorus.—Objectionable, of course, in ores required for the manufacture of low phosphorus iron, its absence being valuable in proportion as to whether a pig-iron of normal or extra purity, demanding a corresponding price, can be produced, and how much less pure ore it will enable to be worked off. On the other hand, for iron such as basic Bessemer, where a minimum percentage is required for the process to be properly carried through, and where the slag is sold as a phosphate, it has a distinct value, and for such a purpose an ore with, say, 0·10 per cent. (too impure for hæmatite), would not be as valuable as if it had, say, 1 per cent., although for basic open-hearth, if the slag were already unsaleable, it would be advantageous, less purification being necessary.

Manganese.—Valued or objected to according to the type of iron to be made. For irons to be worked on acid linings it is objectionable, as it cuts these rapidly, and for certain foundry purposes where it is undesirable to make the iron too hard, as for ingot moulds, it is, beyond a small amount, objectionable. On the other hand, for irons worked on basic linings it is harmless, and up to a certain amount—usually 1 to 1½ per cent. for basic open-hearth where it is used, or higher, say, 2½ per cent., for basic Bessemer—it is advantageous and facilitates proper working. As it is also useful for keeping the sulphur down, it is invaluable for both acid and basic processes, and for foundry purposes, so long as it is not high enough to be harmful on other accounts. The value as affected by these various points may be quite different from that at which it is rated in ores for the manufacture of manganese alloys, as ferro-manganese, spiegel, silico-spiegel, &c.

Carbonic Acid.—Objectionable. Apart from the cost of calcining when necessary, in materials used directly in the blast furnace, extra fuel has to be used to expel it, and as already pointed out extra carbon is dissolved by it.

Silica.—Objectionable. Determined by the cost of limestone, smelting expenses (extra coke, &c.), and removal of extra slag above that usually present in the standard ore for the type of iron. It depends partly on whether it exists free, combined with lime or other base or with ferrous or manganese oxide, &c. These costs do not necessarily correspond with the scale allowances usually made—in fact, these are often ridiculously inadequate and bear no fair proportion either for iron or silica to the true values. The effect of 1 cwt. of silica at four basicities is shown further on.

Lime, and lime equivalents within reasonable limits, are valuable according to how far they reduce the quantity of limestone needed, besides further value if the lime so needed is not associated with carbonic acid, the value on these counts being covered by the "silica fluxed," "coke required," and "slag matters produced" calculation. There is, however, a still further value the more nearly an ore is self-fluxing, because of the greater tendency towards quick smelting; as when once the iron is reduced the earthy matters have simply to melt, and not to arrive at and be dissolved in the slag bath. An objection to ores with a large excess of lime has been mentioned under the head of friability.

Sulphur.—Objectionable beyond certain limits according to the class of pig-iron and slag being made. A good deal of misapprehension on this subject exists, however. For instance, there is generally enough sulphur present in the coke used if it all entered the pig-iron to give at least 1 per cent. But unless the basicity of the slag or the temperature of the hearth falls it does not enter the iron. The worst form of sulphur is pyrites, or sulphides, &c., in which the iron exists in actual contact with sulphur. Directly the iron is reduced the sulphur is ready to seize it, and once combined it cannot be readily decombined. If, however, the sulphur is present as sulphate in combination with lime, baryta, &c., it is far less liable to be decomposed. The author had a very marked experience of this when a certain ironstone with a low pyrites content had to be superseded by other stones with higher pyrites contents, and nothing practicable would get the sulphur down, although ores with higher sulphur, existing as sulphate, would readily yield a low sulphur iron.

Zinc.—Objectionable, especially when 2 per cent. or 3 per cent. is present, on account of the way zinc becomes volatilised and deposited in the downcomers and dust catchers, sometimes furring these up so as almost to close them, and in any event causing increased friction and hindering the free escape of the gases, and, by raising the back pressure at the top, checking the driving. Much zinc found in the gases is objectionable apart from the foregoing (especially if they are used unwashed), both at the stoves, boilers, &c.

Arsenic is generally present in amounts giving from 0·02 per cent. to 0·05 per cent. in the iron, and in these quantities has a negligible effect, beyond tending to make the phosphorus determination show too high when unsuitable analytical methods are used. When appreciably higher, however, it becomes distinctly objectionable if the iron is to be used for steel-making, as, for instance, it affects welding. Much the same considerations apply to antimony.

Titanium, when present in large quantity in ores, renders the smelting more difficult. In small quantities it is frequently present, and many makes of hæmatite iron run from 0·1 per cent. to 0·40 per cent. This amount does not appear to be detrimental to the iron, but the effect on the phosphorus determinations, unless special precautions are taken, is to make them appear too low and so mislead the steel-maker, who finds steel made as "special low phosphorus quality" showing higher than he expected.

Copper.—In the small quantities copper is generally met with in iron ores, giving not more than 0·1 per cent, and usually much lower, it may be regarded as negligible or, in steel from such iron, for some purposes actually beneficial.

Chromium and Nickel.—Certain ores contain these in small quantities, and as these oxides are probably only reduced by solid carbon they cause a slightly higher coke consumption, but they can only be regarded as having a beneficial effect on steel produced from the iron.

Uniformity of Composition and mechanical condition, apart from what these are, is by no means a negligible factor in the value of an ore.

Potash.—If present in appreciable quantity may have to be taken into consideration with a view to its value for recovery.

COMMERCIAL FACTORS.

There are other factors, some of them purely commercial, to which a value can only be assigned for a particular case and not in terms such as are generally applicable. Of these may be cited regularity and continuity of supply, the converse of which may considerably upset furnace working, whilst the manner of supply has already been referred to; the manner of payments and other financial arrangements, incidental sampling costs, &c., have likewise a bearing. These, however, are matters of which the commercial man may be trusted not to lose sight.

Composition of the Natural Pig and Slag.—This from any particular ore whilst taken at a constant composition corresponding to the standard type of pig as regards carbon, silicon, and sulphur will, of course,

* Journal of the Iron and Steel Institute, 1909, No. II, pages 161 and 162.

* Journal of the Iron and Steel Institute, 1917, No. II. page 50.

frequently not correspond so far as the variable elements, phosphorus, arsenic, manganese, iron, &c., are concerned; and may sometimes be of a composition quite unsuitable by itself. Naturally in such a case it could only be used in the burden in such proportion that the average of the whole mixture gave the pig and slag required. Each constituent has its full effect in the proportion used. Credits or debits may, however, have to be given on these accounts; as any extreme—such as 4 per cent. phosphorus in the pig or 30 per cent. alumina in the slag—from that particular ore, may limit its general applicability or enhance its utility in certain circumstances. Some ores may be suitable for two or more types of iron, but have different values for each.

In order to keep down the length of the paper, it has been thought unnecessary to carry any example of valuation to its final money issue, as provided the different points enumerated are recognised and a value assigned for any special conditions affecting the particular works, the current prices and rates can be affixed and completed by the clerical staff. Although for the same reason this brief outline of the principles of valuation is necessarily incomplete, it will no doubt have sufficed to show that correct valuation is by no means the simple matter it might be thought, or suitable to be settled by mere bargaining and that there is a far better chance of buying or selling to advantage when the buyer has carefully worked out data to go upon.

A study of the values of ores along the lines described reveals a number of interesting points, only a few of which can be touched on. One of the first is the almost startling differences in the values of various ores generally regarded as substantially equal, as, for instance, how rapidly an ore deteriorates in value as it becomes more siliceous. Thus one delivery of ore may be good value, and it may be quite bad business to use another of the same ore which is only "a little worse." As an instance may be cited ironstone from the same mine, delivered over different periods, and all sent at the same price as of equal quality, but of three degrees of cleanliness.*

A point to note is that frequently a high-priced ore is really much cheaper than a low priced one, whilst conversely a rich ore of a certain character may have much less value than one a good deal lower in iron but of another type. From the iron-maker's point of view it is, further, generally uneconomical that dirty and shaly ores, or poorer seams, should be worked, owing to the excessive limestone and coke consumption necessary if the proper basicity of the slag is maintained; whilst from the national need for fuel economy this deserves very serious attention, at any rate as regards cleaning such ores as much as possible.

The introduction of 1 cwt. extra silica into the blast-furnace involves, by the time it has passed out as slag, the following :—

For a slag basicity	2	1·8	1·7	1·5
	cwt.	cwt.	cwt.	cwt.
Limestone required	4·12	3·68	3·47	3·04
Coke required	2·42	2·2	2·09	1·86
Extra weight to charge, apart from 1 cwt. silica	6·54	5·88	5·56	4·90
Slag produced	3·47	3·2	3·09	2·82
Total solids to handle	10·01	9·08	8·65	7·72
Blast required	12·10	11·0	10·45	9·30

The cost of the first example, apart from blast, at prices at the date of writing, is about 9s. One cwt. is 5 per cent. of a ton, so it can be seen how serious is 5 per cent. more silica in a ton of ore of which 2 tons or 3 tons are required per ton of pig. The subject of the very great effect of impurities thus opens up a larger question than that of merely buying and selling to advantage.

Many of the native stones are not sold in open market but owned by iron-makers, and if they, by careful loading or cleaning, minimise the impurities, they get the full money value with certainty, whereas if they were selling they would have to persuade the buyer to give the extra price. The author pointed out at a meeting in 1907 of the Cleveland Institution of Engineers how uneconomical it was even then, with cheap coke and limestone, to bring away dirt from the mines, and from this point of view—whilst, of course, not presuming criticism of its correctness in law—a judgment given a few months ago in favour of material being filled in the mines with shovels instead of gripes seems amazing, seeing that the small so picked up (whether of coal or ironstone) is almost invariably higher in siliceous and slag-forming matters, and entails, as shown, a disproportionately large coke consumption, and hence waste of fuel. In general, economic considerations for the nation's welfare the effect of any given course should be looked at not only from the point of view of one stage, but from the ore and fuel in the mine to the ingots or even to a still further worked-up product. If equity towards the miners necessitates the course mentioned, equity towards the iron-maker, as well as the national need for fuel economy, demands that any shaley or other siliceous materials which can easily be separated and avoided should be dealt with in some manner other than charging them into blast-furnaces, occasioning unnecessary waste of transport, fuel, labour, &c. This consideration, coupled with the number of ores which contain much dust, or crush readily, and also the fact that the ores richest in iron are magnetic (which whilst not reducible economically by carbon monoxide in the upper part of the furnace, yet require for direct reduction by solid carbon less than peroxide, viz., only eight-ninths), raises the question whether the most economical method of removing impurities and reducing iron will continue for long to be the blast-furnace; or whether some other method will supplant it, such as grinding and purifying by a pneumatic, magnetic, or analogous method, the purified dust be reduced by a direct process with the consumption of little more than a third of the carbon at present required, the necessary heat being supplied by cheap electricity—possibly from power generated in large central stations from the combustion of the poorer and small varieties of coal, at present of little value.

When, if ever, such a state of things arrives, quite possibly the necessity for working seven days a week may cease. However visionary this may appear, a study of these blast-furnace reactions and all that is involved in the treatment of impure ores is well worth careful consideration.

There are many other questions it would have been interesting to touch on, such as the ready applicability of the system described to burdening, and rapidly gauging the effect all through of the substitution of one ore for another, the importance of more exact calcination of raw stones of the ferrous carbonate type, so as to avoid the detrimental effects both of raw stone and scar, and the very great practical effect of small losses of heat in the hearth on the coke consumption and product. These, however, would unduly lengthen the paper.

The author, in conclusion, acknowledges the help which the late Sir Lowthian Bell's book, "The Principles of the Manufacture of Iron and Steel," was to him in his early studies of these subjects, also the work of Mr. H. E. Wright and Mr. W. Wilson in connection with the earlier calculations, which later, had been carried on by Mr. C. Wilkinson, all of whom he has been fortunate to have had for assistants in the past.

* This was in 1904 and early in 1905, and the author was very pleased when his own experience was entirely confirmed in a paper by the late Mr. T. C. Hutchinson, "The Mechanical Cleaning of Iron Ores," Journal of the Iron and Steel Institute, 1908, No. III; see particularly Tables IV and IX, pages 44 and 49. This was again confirmed by his ten years' experience given in his further paper, "Fuel Economy in Blast Furnaces," *ibid.*, 1918, No. I, page 128.

"THE PERFORMANCE OF MECHANICAL STOKERS."

To the Editor of Engineering.

SIR,—With regard to the letter of Mr. C. Percy Taylor, on page 590 of your issue of April 30, the method he describes of testing the various appliances, including mechanical stokers, on the market, is eminently sensible and practicable. There is no doubt that on small boiler plants of one or two "Lancashire" boilers, chimney draught, economisers, superheaters and hand-firing, under good conditions, will require a lot of beating with average quality coal. Each boiler plant must, however, be considered entirely on its merits and hardly any two boiler plants are alike.

It is really most amazing how "patent" appliances of every description, many of them of the craziest and most impossible design, find a ready sale among steam users. These appliances are installed with hardly the slightest investigation, and almost invariably no proper records are kept as to their performance. There seems to be no end to the supply of such "aids" to coal economy, although certainly within the last few years the number of mysterious boiler compositions seems to have slackened off.

In my opinion, Mr. Taylor is quite correct in pointing out that the small boiler plant will always be with us.

Advocates of the super-power station scheme coolly ignore the fact that probably, 15,000,000 tons to 20,000,000 tons of coal is burnt per annum under boiler plants for low-pressure steam alone. In many industries such as bleaching, dyeing, finishing, brewing, chemical processes of almost every description, and so on, the amount of steam required for power is only a small proportion of the total steam demand. The question, therefore, of a national power supply is of little or no direct importance to all these industries, and it is essential that their boiler plants should be brought up to date.

Yours faithfully,

Manchester, May 3, 1920. D. BROWNLIE.

GENERAL CONDITIONS IN ENGINEERING CONTRACTS.

To the Editor of Engineering.

SIR,—I wish to thank your reviewer for his helpful criticism of my book "General Conditions in Engineering Contracts" (April 16, 1920). Should opportunity occur advantage will be taken of several of his suggestions. I regret, however, that he thought the quotation from Lord Chelmsford's judgment in Thorn *v.* Mayor of London was misleading. Whether that case was rightly decided by the House of Lords [I.A.C. 120] or not, it is settled law and though Lord Chelmsford's words are strong they sum up, not unfairly, the decision. The headnote runs: "Where plans and a specification for the execution of a certain work are prepared for the use of those who are asked to tender for its execution the person asking for tenders does not enter into any implied warranty that the work can be successfully executed according to such plans and specification." In this case the plans and specification showed that a bridge was to be built by the use of caissons and the contract provided that while the information regarding foundations, &c., was believed to be correct it was not guaranteed, and the contractor must satisfy himself as to the nature of the ground. The use of caissons turned out to be impracticable, and all the labour given to the execution of the original plans was wasted. The contract price was duly paid and also the cost of extra work rendered necessary by the alteration, but the contractors, in effect, brought an action to recover compensation for loss of time and labour in his abortive attempt to carry out the original plan. This the Court refused to give on the ground that there was no warranty on the defendant's part that the work could be carried out as specified. It was the duty of the contractor to examine the plans or to employ a competent person to examine them. It was said in argument that it was the usage of contractors to rely on the specification and not to examine it particularly for themselves. It is this which Lord Chelmsford characterised as "an usage of blind confidence of the most unreasonable description." Mr. Hudson, in his work on "Building Contracts," states the law thus: "The duty of contractors is to see for themselves if they can perform the work or not, and if they rely on the skill of the engineer employed by the building owner or employer they must do so at their own risk."

It is possible to argue that the law should be altered or to contract out of it so far as may be, but I do not think I have mis-stated it.

I am, Sir, yours truly,

W. S. KENNEDY.

Harcourt Buildings, Temple, E.C., April 28, 1920.

UNIVERSITY OF LONDON, UNIVERSITY COLLEGE, ENGINEERING SOCIETY.—The annual dinner of the Engineering Society, University College, will be held on Tuesday, the 18th inst., at Frascati's Restaurant, at 7 p.m. Any past members wishing to be present should communicate with the Dinner Secretary, Gower-street, S.W. 1.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.—The list dated April 1, of Research Associations which have been approved by the department as complying with the conditions laid down in the Government scheme for the encouragement of industrial research and have received licences from the Board of Trade under Section 20 of the Companies' (Consolidation) Act of 1908, include: The British Iron Manufacturers' Research Association, Atlantic Chambers, Brazennose-street, Manchester (secretary, Mr. H. S. Knowles); the Research Association of British Motor and Allied Manufacturers, 39, St. James's-street, London, S.W. 1 (secretary, Mr. Horacé Wyatt); the British Portland Cement Research Association, 6, Lloyd's-avenue, London, E.C. 3 (secretary, Mr. S. G. S. Paniseet, A.C.G.I., F.C.S.); the British Scientific Instrument Research Association, 26, Russell-square, W.C. 1 (secretary, Mr. J. W. Williamson, B.Sc.); the Research Association of British Rubber and Tyre Manufacturers, care of Messrs. W. B. Peat and Co., 11, Ironmonger-lane, E.C. 2; the Glass Research Association, 50, Bedford-square, W.C. 2 (secretary, Mr. E. Quine, B.Sc.); and the British Non-Ferrous Metals Research Association, 29, Paradise-street, Birmingham (secretary, Mr. E. A. Smith, A.R.S.M., M.Inst.M.M.).

THE INSTITUTION OF CIVIL ENGINEERS.—The Council of the Institution of Civil Engineers have made the following awards for papers read and discussed during the Session 1919–20: Telford gold medals and Telford premiums to Mr. David Lyell, C.M.G., C.B.E., D.S.O. (London); Mr. J. K. Robertson (London), and Major-General Sir Gerard M. Heath, K.C.M.G., C.B., D.S.O., R.E. (London); a George Stephenson gold medal and a Telford premium to Mr. Maurice F. Wilson (London); a Watt gold medal and a Telford premium to Mr. P. M. Crosthwaite, B.A.I. (London); Telford premiums to Major E. O. Henrici, R.E. (London), Sir Francis J. E. Spring, K.C.I.E., M.A.I. (London), Mr. F. O. Stanford, O.B.E. (London), Mr. James Mitchell (Hursley), Mr. J. W. Sandeman (Newcastle-on-Tyne), and Mr. A. R. Fulton, D.Sc. (Dundee). At the annual general meeting of the Institution, held on Tuesday, April 27, the result of the ballot for the election of officers for the year 1920–21 was declared as follows: President: Mr. John A. Brodie, M.Eng. (Liverpool); Vice-Presidents: Mr. W. B. Worthington, B.Sc. (London), Dr. W. H. Maw (London), Mr. Charles L. Morgan, C.B.E. (London), Mr. Basil Mott, C.B. (London); other Members of Council: Mr. E. A. S. Bell, C.I.E., F.C.H. (India), Dr. C. C. Carpenter, C.B.E. (London), Colonel R. E. B. Crompton, C.B. (London), Mr. Maurice Deacon (Matlock), Sir Archibald Denny, Bart. (Dumbarton), Sir William H. Ellis, G.B.E., D.Eng. (Sheffield), Mr. Albert Gordon, M.A.I. (Dublin), Mr. W. W. Grierson, O.B.E. (London), Sir Robert A. Hadfield, Bart., D.Sc., D.Met., F.R.S. (London), Sir Brodie H. Henderson, K.C.M.G., C.B. (London), Mr. E. P. Hill (London), Mr. G. W. Humphreys, C.B.E. (London), Mr. Summers Hunter, C.B.E. (Tynemouth), Mr. H. G. Kelley (Canada), Mr. C. R. S. Kirkpatrick (London), Mr. James Marchbanks (New Zealand), Mr. H. H. G. Mitchell (India), Engineer Vice-Admiral Sir Henry J. Oram, K.C.B., F.R.S. (Rudgwick), Mr. Frederick Palmer, C.I.E. (London), Captain H. Riall Sankey, C.B., C.B.E., R.E. (retired) (London), Sir John F. C. Snell (London), Mr. W. A. P. Tait, B.Sc. (Edinburgh), Mr. A. M. Tippett (South Africa), Mr. E. F. C. Trench, M.A., B.A.I. (London), Professor W. H. Warren (Australia), Sir Alfred F. Yarrow, Bart. (Hindhead). This council will take office on the first Tuesday in November, 1920.

THE CERAMIC SOCIETY.

THE Refractory Materials Section of this society held their seventh meeting on April 28 and 29, at the Central School of Science and Technology, Stoke-on-Trent. The president, Sir W. J. Jones, occupied the chair, and the attendance of members was very large.

The papers read on the first morning included "Carboniferous Grits of Denbighshire and Flintshire," by T. A. Acton, F.S.A., F.G.S., "The Refractory Materials of the North Staffordshire District," by Dr. A. Scott, and "The Analysis of Zirconium Minerals," by H. V. Thompson, M.A. Sir W. J. Jones then exhibited and explained the construction of a high-pressure oil burner from a glass works. The burner was invented by Mr. Stevens, and was worked with a 50 per cent. mixture of creosote and pitch. The oil was introduced to the burner by a drip feeder, from a storage tank placed 10 ft. above the burner, at a temperature of 100 deg. F. (maintained by low-pressure steam). The oil was atomised, and at the same time air was sucked in. On the front of the burner was an annulus, which received air at the same pressure, and this prevented the atomised oil from spreading too quickly. A single burner sufficed to heat a furnace 14 ft. by 8 ft. by 4 ft. deep (or more), in which were eight glass pots. Very uniform and very efficient heating resulted; the plaining temperature of the glass being 1,500 deg. C. About 16·8 gallons of oil per hour were consumed. It was suggested that such burners might answer well for heating gas retorts, frit kilns, and kilns for calcining flint. The great trouble at present is the enormous cost of liquid fuel of any kind.

In the afternoon the papers were "Note on the Influence of Grog in Admixture with Clay," by W. C. Hancock, B.A.; "The Corrosion of Coke-Oven Walls, II. The Action of Salt on Silica and Fireclay Bricks," by W. J. Rees; "Fused Artificial Sillimanite," by A. Malinovszky; and "Psychological *versus* Scientific Management," by Dr. C. S. Myers. We subjoin abstracts of some of the papers:

Carboniferous Grits of Denbighshire and Flintshire.

By T. A. ACTON, F.S.A., F.G.S.

The carboniferous limestone and overlying Cefn y Fedw sandstones in Eastern Denbighshire and Flintshire occupy an area about 55 miles long and 2 miles to 5 miles wide, stretching south from the Point of Ayr and Rhyl, by Holywell, Flint, Mold, Minera (west of Wrexham), Trevor (east of Llangollen), Chirk, to end abruptly at Llanymynech (south-west of Oswestry), overlooking the Shropshire triassic plain. It forms the western edge of the North Wales coalfield. The only serious disturbance is the great Bala fault, which at Llandegla divides the Flintshire and Denbighshire coalfields.

The late G. H. Morton (of Liverpool) first pointed out that the rocks then called millstone grits of North Wales included the millstone grit and the Yoredale rocks of Staffordshire, Derbyshire and Yorkshire. This view is confirmed by the recently published memoir of the Geological Survey, which states that the greater part of the Cefn y Fedw sandstone is probably older than the millstone grit of Derbyshire, and is a local development of sandstone on the top of the carboniferous limestone series. Cefn y Fedw forms the summit, about 1,650 ft. above sea level, of the moorlands above the Eglwyseg rocks north of Llangollen. The average thickness of the grits is about 750 ft.

In the Midland plain of England, to which these Welsh rocks seem to be connected, the carboniferous beds are largely concealed by newer deposits. On the western margin of the plain they crop out in a narrow strip against the old rocks of the Welsh hinterland. In Derbyshire, due east of the Dee, the carboniferous limestone is in places 2,000 ft. thick. In North Wales the average thickness is about 1,100 ft. Thus the carboniferous sea probably overspread Derbyshire from the south before it reached North Wales.

In the Dyserth, Flint, Holywell and Halkyn district the chert beds are a marked feature, and about Holywell and Halkyn the cherts, grits and upper and middle limestones are rich in mineral veins (galena and blende). The chert has been worked in several places to furnish blocks for grinding mills in the Potteries. Some of these chert beds were undoubtedly limestones originally, but silica has replaced carbonate of lime.

The lithological features of the limestones all over the district are fairly uniform and best developed about Llangollen. Mr. Morton gives them as:—

	Feet.
Sandy limestone....	75
Upper grey limestone	300
Upper white limestone	300
Lower white limestone	210
Lower brown limestone	180

Both the limestones and the Cefn y Fedw sandstones contain beds of shale.

The sandy limestone is the lowest subdivision of the Cefn y Fedw series. It is rich in silica, and is usually a flaggy sandstone; it contains numerous fossils, especially encrinite stems. The lower sandstone is very hard, and contains no carbonate of lime. Sometimes it forms conglomerates.

Cambria clay is a white clay with 80 per cent. silica and practically no iron. It is found in pockets and fissures of limestone in the Halkyn, Mold and Minera district. This clay seems to have been brought in by underground streams. The white colour may be due to washing from marshy spots, the vegetable acids dissolved in the water having removed the iron and other impurities.

In the Gresford district, in the unproductive upper coal measures, the series of red, grey and green shales, with red and grey sandstones, make their first appearance, and south of Wrexham and on to Ruabon, and along the Dee Valley south-east therefrom, develop into a great thickness of red sandstones and red marks, which contain the well-known Ruabon red marks worked as terra cotta clays.

The Refractory Materials of the North Staffordshire District.

By Dr. A. SCOTT.

Silica refractories are found mainly in the Pendleside series, which includes several seams of "ganister" or "crowstones," having a thickness up to 6 ft. They include three types: (*a*) Hard grey rock like that of the Sheffield district, containing 95 per cent. to 97 per cent. silica, and with refractory test cone 33 to 35; (*b*) very hard blue rock, with over 97 per cent. silica, and refractory test over cone 35; (*c*) silicified sandstones of less hardness, with 92 per cent. to 96 per cent. silica, and refractory test cone 30 to 35. Microscopic examination shows quartz grains surrounded by thin cementing layers of secondary silica. In some cases secondary silica is in optical continuity with quartz. Sometimes the cement is crystalline interstitial quartz. Felspar is rare, but occasional heavy detrital minerals are common.

They are found under the grits along Congleton Edge (from Mow Cop northwards)—at least six different beds have been worked. These are intercalated with shales containing typical Pendleside fossils. Also in Lask Edge, between Biddulph Valley and Rudyard. There is a large development to the north of the River Dane at Bosley Minn, and northwards to Macclesfield. Also north-west of Leek at Gun End, &c. In the coal measures, ganister which is the stratigraphical equivalent of the Sheffield hard bed ganister occurs under the Crabtree coal in the Churnet Valley, but north-west it tends to pass into fireclay. On Metley Moor the underbed is now refractory white plastic clay.

Silicious materials in the form of sands and clays are found in pockets in North Staffordshire and Derbyshire. These originate almost certainly from old river deposits. Similar material found recently probably represents large swallow-hole. The millstone grit is characterised by a high percentage of felspar, and also contains barytes. Such material used for pottery is liable to develop "blue specks," the cobalt stain being segregated in the baryta. The local fireclays (or "marls") are somewhat silicious, and not very refractory, though sufficiently so for most local purposes.

The Analysis of Zirconium Minerals.

By H. V. THOMPSON, M.A.

In this paper the author points out that in practice two difficulties are encountered; the opening up of raw zirconium ores, and their products is by no means easy, and separation of aluminium from zirconium is not easy. The first of these difficulties is overcome by the use of sodium peroxide, which when fused with zirconium minerals opens them up rapidly and completely. Incidentally this treatment facilitates the solution of the second difficulty, for after the action of water on the mass, and filtering, all the alumina with some silica is found in the filtrate, whilst all the iron, titanium and zirconium oxides, with the rest of the silica, are present in the residue. The other determinations necessary present no special difficulty.

Note on the Influence of Grog in Admixture with Clay.

By W. C. HANCOCK, B.A.

In this note Mr. Hancock recalls that the general effects of addition of grog to plastic clays, as is well known, include reduction of air shrinkage and fire-shrinkage, increase in rate of drying, reduction of warping tendency, and often reduction of tensile strength and increase in porosity. The quantitative effect on these properties depend on the grain size of the grog, as well as on the proportion added.

In practical work of students in the Refractory Materials Course at the Imperial College of Science and Technology, small test pieces are moulded from neat clay and from mixtures of clay and grog. The test-pieces for shrinkage, etc., are blocks 10 cm. by 2·5 cm. by 2·5 cm. (about 4 in. by 1 in. by 1 in.), and those for tensile strength are of the usual shaped briquettes. The plastic Stourbridge fireclay used is ground to pass a sieve of 30 meshes to the linear inch, and mixed with water until apparently in proper working condition. After the moistened mass has matured for a time, the test-pieces are moulded and weighed at once, then left to dry in the air, and weighed after being some time in a hot-air oven at 105° C. The difference between these weights gives the amount of tempering water. The grog was made by firing some of the same clay until thoroughly shrunk, then crushing and sieving. The portion which passed a sieve with $\frac{1}{8}$-in. meshes and was retained by a sieve with $\frac{1}{16}$-in. meshes was used for making the test-pieces.

The following shows results (taken more or less at random) of tests made on blocks of neat clay and of a mixture containing 80 clay to 20 grog. The percentages of water are calculated on the weights of the blocks after drying at 105° C., and the percentage shrinkages on the original wet lengths, the fire-shrinkages being the total contraction from the wet length after firing to about 1,200° C.

Student.	Neat Clay.			Clay 80 : Grog 20.		
	Water.	Shrinkage.		Water.	Shrinkage.	
		Air.	Fire.		Air.	Fire.
No. 1	19·1	5·6	8·0	18·8	4·0	5·4
No. 2	17·7	5·7	—	15·0	—	—
No. 3	16·8	5·4	7·8	17·0	4·4	4·9
No. 4	18·0	—	—	17·7	—	—
No. 5	18·3	5·5	8·5	16·6	3·0	4·2
No. 6	19·4	5·5	8·1	16·0	4·2	—
No. 7	19·8	5·1	—	15·3	—	—
No. 8	19·0	5·2	8·7	16·5	3·4	5·4
Mean ..	18·5	5·4	8·2	16·6	3·8	5·0

The corresponding percentages of water in the tensile strength briquettes were 18·4 in the neat clay and 16·8 in the clay-grog pieces. Though too much reliance cannot be attached to the results, the tensile strength obtained were:—

Unfired.—Neat clay, 120 lb. per square inch.
Fired—Neat clay, 960 lb. per square inch.
Unfired.—Clay-grog, 60 lb. per square inch.
Fired.—Clay-grog, 400 lb. per square inch.

Other series of test-pieces were made up with a view to ascertaining how the proportion and grading of the grog affected the amount of tempering water. The following results were obtained:—

—	Water.	Shrinkage.	
		Air.	Fire.
	per cent.		
Neat clay	18·5	5·25	8·20
Clay 90 : grog 10 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.) ..	17·3	4·47	7·25
Clay 80 : grog 20 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.) ..	16·6	3·33	5·46
Clay 70 : grog 30 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.) ..	15·0	3·08	4·17
Clay 80 : grog 20 ($\frac{1}{16}$ in. to $\frac{1}{32}$ in.) ..	17·5	3·93	6·05
Clay 60 : grog 40 ($\frac{1}{16}$ in. to $\frac{1}{32}$ in.) ..	15·9	3·24	3·97

These tests were all made by the same observer, and the figures are the mean results of a number of test-pieces in each series.

The amount of tempering water clearly decreases as the grog (of a particular grade) increases, but the amount of water increases with finer grained grog.

As regards distribution of the water between clay and grog, it was assumed that the clay would take up a proportionate amount of that taken up by neat clay; thus if dry clay takes up 18·5 per cent. water to bring it into proper workable condition, the clay in a mixture of 90 clay to 10 grog would take up 90 per cent. of 18·5, or 16·65 per cent. of water; the difference between this and the actual amount required would, of course, go to the grog. Applying this method of calculation to the previous results, the following values are obtained:—

—	Total Water.	Water in Clay.	Water in Grog.	Percentage of Water in Grog.
Neat clay	18·5	—	—	—
Clay 90 : grog 10 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.)	17·3	16·65	0·65	6·5
Clay 80 : grog 20 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.)	16·6	14·80	1·80	9·0
Clay 70 : grog 30 ($\frac{1}{4}$ in. to $\frac{1}{16}$ in.)	15·0	12·95	2·05	6·8
Clay 80 : grog 20 ($\frac{1}{16}$ in. to $\frac{1}{32}$ in.)	17·5	14·8	2·7	13·5
Clay 60 : grog 40 ($\frac{1}{16}$ in. to $\frac{1}{32}$ in.)	15·9	11·4	4·8	12·0

The same method of calculation was applied to

results of other experiments carried out for quite a different purpose, using the same clay and grog, all being done very carefully by the same observer. The grog, however, was of three grades (including the two grades as above) shown following: A. Fine. All passed a 30-mesh sieve, but was retained by a 60-mesh. B. Medium, $\frac{1}{16}$-in. to $\frac{1}{8}$-in. as before. C. Coarse, $\frac{1}{4}$-in. to $\frac{1}{16}$-in. as before. The results were:—

	Total. Water.	Water in Clay.	Water in Grog.	Percentage of Water in Grog.
Neat clay	18·0	—	—	—
Clay 80 : grog A20 ..	21·0	14·4	6·6	33·00
Clay 60 : grog A40 ..	20·0	10·8	9·2	23·00
Clay 80 : grog B20 ..	20·1	14·4	5·7	28·50
Clay 60 : grog B40 ..	18·0	10·8	7·2	18·00
Clay 80 : grog C20 ..	19·4	14·4	5·0	25·00
Clay 60 : grog C40 ..	14·9	10·8	4·1	10·25

Again, the finer the grog the more water attached to it, but for the same grade the amount of water seems to diminish as ratio of grog to clay increases. The author accounts for the discrepancy by stating that the mass from which the test-pieces showing the larger amounts of water were made was much better rugged, and stored much longer before working.

(To be continued.)

INDUSTRIAL NOTES.

ACCORDING to *The Board of Trade Journal* the coal output for the week ended April 17 was 4,833,072 tons. In reply to questions by Mr. Lambert and Colonel Newman in the House of Commons, Mr. Bridgeman, Parliamentary Secretary to the Board of Trade, said that the cost of wages per ton of coal raised at the pit's mouth was 6*s.* 4·01*d.* in 1913 and 18*s.* 7·68*d.* in 1919; the number of persons employed in the industry were 1,110,884 in 1913 and 1,163,000 in 1919, and the output per person (above and below ground) was 259 tons for 1913 and 197½ tons for 1919. The cost approximately of the recent increase in wages was estimated to be 31,500,000*l.*, apart from certain incidental and consequential increases.

Speaking at the twenty-first ordinary general meeting of Messrs. Fairbairn, Lawson, Combe Barbour, Limited, held in London on the 28th ult., Mr. J. Campbell Inglis, the chairman, said: "No one can say what will be the end of the continual rises in the cost of labour, but I must again remind you that there is a limit to what the consumer will pay. The price of our machinery has risen to a very high level, and we have to face, not only the possibility of reduced demand, but also that of increased competition. Let us not forget that there are other countries capable of producing machinery who will be only too glad of the opportunity of annexing our trade. You may ask what is the remedy. It is easy to reply, "Increase the output," but how is that to be done? We say emphatically that the only effective system is one of payment by results. We are willing to pay liberally for increased production and to introduce every possible safeguard for the men. I know that there is a feeling of suspicion among the men that the moment a system of payment by results shows good results for the men the employers seek to revise the system to the detriment of the men. They need have no such fear, for it is an essential feature of the conditions proposed by our federation that no such change shall be capriciously made, but must be justified by changes of method. The federation is doing its best to secure freedom for employers to introduce systems of payment by results, and the question is now being ballotted on by the engineering unions. It is only by increased production that our country can return to its former condition of financial stability, that the cost of living can be reduced, and that the pound sterling can escape from the discredit of its present depreciation in exchange."

The question of payment by results was also referred to by Sir Charles E. Ellis, chairman of the English Electric Company, Limited, at the first ordinary general meeting of the company held in London on the same day. Sir Charles also alluded to the effects of the recent moulders' strike, and stated: ". . . There are certain indications that the relations between employers and employed are becoming less strained. The disturbance which quite naturally resulted from the rapid demobilisation of so many workmen from the Army, and the quite natural anxieties of the trade unions concerning their post-war working conditions are being slowly, but I feel nevertheless surely, overcome, and the recent decision of the National Federation of General Workers to accept payment by results, together with the agreement of the Amalgamated Society of Engineers to subject this question to a ballot of its members, are favourable portents for the future. While, therefore, for the next year or so the position cannot be free from anxiety, I believe that the more moderate elements of labour show indications of their willingness to co-operate with us, provided they can see a fair and reasonable basis for compromise. This is a general outline of the activities at home, and generally speaking, the year has been mainly devoted to the consolidation and organisation of the different units. It is believed that for the most part this has now been accomplished, although much has yet to be done in detail. During last year very little real production of electrical and allied apparatus took place. The earlier part of the year was devoted to rearrangement of shops and remodelling in design, and we were just getting on to a producing basis when the unfortunate strike of moulders found us with none of the stocks of our raw material which would have been available in normal times, and therefore we were under the necessity of immediately reducing output by in some cases discharge of employees and in others the working of short hours. The effect still remains even after 13 weeks since the settlement. We are perhaps more fortunate than some in that we have three excellent foundries in our group, but they are handicapped by the shorter hours worked and the fact that piecework arrangements have not been yet agreed to. The importance of this question cannot be over-estimated, as the engineering output of the country is at present limited by its foundry capacity. . . ."

The Executive of the National Federation of General Workers met last Friday, under the chairmanship of Mr. J. R. Clynes, to complete the arrangements for the ballot of 100,000 gas workers throughout the country on the question of striking to enforce the claim for an increase in wages of 10*s.* per week, overtime, and annual holidays. It was decided that the ballot papers should go out as soon as possible and be made returnable to the federation by the 18th inst. The executive will meet on the following day to consider the result and take the necessary action. The papers will contain a statement of the issue setting forth the claim and the employers' reply, and the men will be asked to state "Yes" or "No" on the question as to whether they are in favour of tendering notices to cease work. In the event of the ballot showing a majority for a strike, the executive will arrange for notice to be given for a cessation of work on a general date at all undertakings involved.

It is stated that the employers are about to issue a statement of the case from their point of view, giving facts and figures of the financial position of the industry and of various undertakings.

Speaking in London last Friday, Mr. C. T. Cramp, Industrial Secretary of the National Union of Railwaymen, said that the railwaymen's present demand for a flat-rate increase of 1*l.* per week must be satisfied. He wanted to make it clear to those who had not had the opportunity of thoroughly grasping the reason for the demand that the settlement arrived at this year could in no way be regarded as a final settlement. It was to be regarded as something accepted under pressure and under protest. They had to choose between accepting that settlement or again throwing the country into a state of chaos. They accepted it at the time because it contained principles which were good and which might be improved upon. But it was in no sense a finality. That being established the executive then said: "Now is the time when we should launch a further movement, not merely to keep up with the cost of living, but to raise the standard of the basic rates of all railwaymen." They were now being told that because the settlement was only recently arrived at it was the desire of the railwaymen to throw the settlement overboard. It was nothing of the kind. It was a reaffirmation of the railwaymen's demand to be raised to a higher status in the industrial population. A mixed commission having agreed that the minimum rate for dockers was to be 16*s.* per day, surely they were not going to say that the railwaymen were not entitled to a modest 1*l.* more a week.

As will be noticed, Mr. Cramp's above remarks are similar to those he made on a former occasion, as reported on page 510 *ante*.

The Central (Railway) Wages Board met at the Midland Grand Hotel, St. Pancras, last Tuesday, to consider the railwaymen's claims, and at the close of the meeting the following official report was issued: "After full discussion of the respective claims of the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen, on behalf of their members, the Central Wages Board was unable to reach an agreement, and the applications will therefore be referred to the National Wages Board. A further meeting of the Central Wages Board will be held in the course of a few days to settle the exact terms of reference to the National Wages Board."

Mr. J. H. Thomas, M.P., addressing a meeting of railwaymen at Derby last Sunday, said there was unrest in the railway world, and this was likely to continue whilst no regard was shown to the relationship of one industry to another in reference to pay. There was, however, machinery to deal with the matter, without either prejudice or intimidation. Recently, he added, a section of the press went out of its way to prejudice the question, and he protested in the interests of the men. At the present time, Mr. Thomas further stated, attempts were made by a certain section of the men to introduce a new economic weapon, known as the "slow gear" or "working to rule." He frankly admitted that there were many rules in the railway service to-day that were either obsolete or needed amending, but why not demand a revision of those rules? Why not clearly put forward the objections to them, and the public would at least be able to recognise the justice of the claim. What will be the effect if this new policy is carried in operation, and who will suffer? He had no hesitation in saying that the first to suffer would be the workers themselves. "Do not let us minimise," Mr. Thomas stated, "the need of good, swift and efficient transport which at this moment is more essential than ever. Do those who advocate such a policy realise that it is the one certain method of further increasing the cost of living. And who is it directed against? Not the railway companies—they are guaranteed and will not suffer a loss whatever the consequences. Not the Government—they can call upon the taxpayers to make up any loss. It is nothing short of a war on the community, and has all the elements of poison gas."

Mr. T. Richards, M.P., general secretary of the South Wales Miners' Federation, addressed a meeting of miners at Aberdare last Saturday and stated that federation matters could not be made subservient to the Irish and Russian questions, important as these were. There were individuals who were out to destroy the federation and to declare themselves, if they succeeded, masters of the situation without offering any organisation in substitution. Law and order were imperative for the success of any trade organisation, and, if the extremists prevailed, this country would be seething with the chaos and suffering which prevailed in Russia. He advised the meeting carefully to watch such individuals and not only to appoint their leaders themselves, but to tell them what to do. As long as he had breath he would protest against the action of these young men who, regarding democracy as too dull and too slow, were out to wreck all that was constitutional in this country.

A meeting was held last Monday at the Guildhall, the Lord Mayor presiding, in support of the Housing Bonds scheme. In the absence of the Prime Minister through illness, Mr. Bonar Law addressed the meeting, and stated that schemes for 180,000 houses and tenders for over 100,000 had been finally approved; work was in progress on 30,000 houses. Progress, however, was being hindered for want of financial means, and the appeal was made to local authorities to stimulate local patriotism and local feeling and, to the utmost extent to which that was possible, to secure local financial assistance in carrying out the scheme and make this a complete success.

INCORPORATED MUNICIPAL ELECTRICAL ASSOCIATION.—This association has issued a programme for the twenty-fifth annual convention to be held at Bradford and Ilkley, from June 21 to 25 next. Further information can be obtained from the Secretary, Electricity Works, Factory-lane, Croydon.

THE SOCIETY OF ENGINEERS (Incorporated).—A paper on "The Assessment to the Poor Rate of Engineering Undertakings" was read before the Society on the 3rd inst., by Mr. W. G. Cooke, A.R.I.B.A., Assoc.Inst.C.E. Member of Council, in the rooms of the Geological Society. The subject was divided into two parts. The first dealing with those companies such as gas and water, where the rateable value was ascertained from the yearly accounts as issued to their shareholders; and the second, such as general engineering works, breweries and the like, where the rating was ascertained on the basis of cost and adaptability of the premises to the particular trade carried on. Mr. Cooke showed how, the working expenses being increased, the hypothetical tenants share (a further deduction) was also increased by the high prices of meters, tools and other chattels. The most marked increases were in the statutable deductions, that is, over the cost of repairs, renewals and insurance, or, in one word, "upkeep." The cost had gone up from 200 per cent. to 300 per cent. over pre-war figures, and even if the gross value, according to the statutory definition, were unaffected, the rateable value or basis upon which the rates were payable would be considerably reduced. This latter phase would, perhaps, be more distinctly noticeable in the second-class of hereditaments, because, where no variation of either income or working expenses can be brought in, one gets to look upon the gross value as a fixed or unalterable figure, where no enlargement of building or additional machinery had taken place or been installed.

EXPERIMENTAL ENGINE AT UNIVERSITY COLLEGE, CARDIFF.

CONSTRUCTED BY MESSRS. MARSHALL, SONS AND CO., LIMITED, ENGINEERS, GAINSBOROUGH.

Fig. 1.

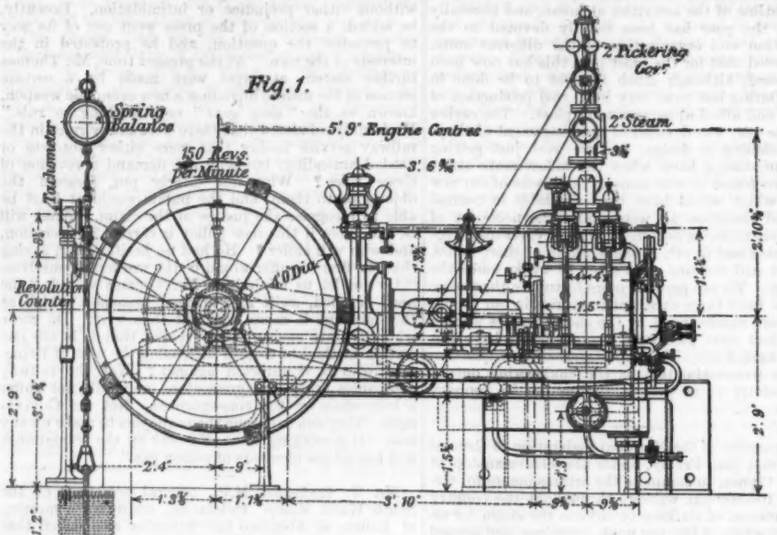


Fig. 2.

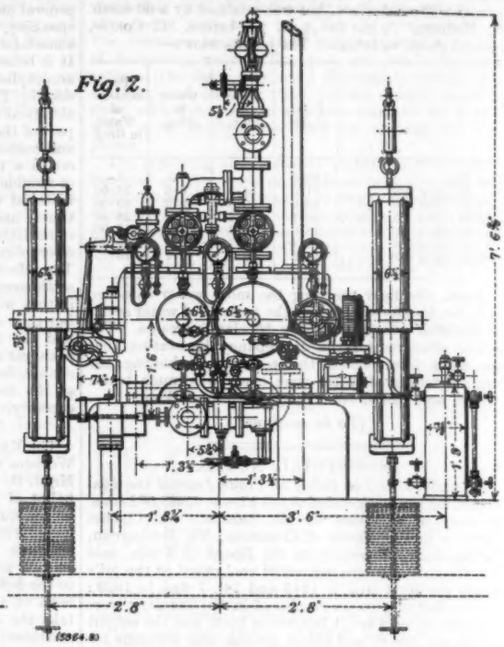
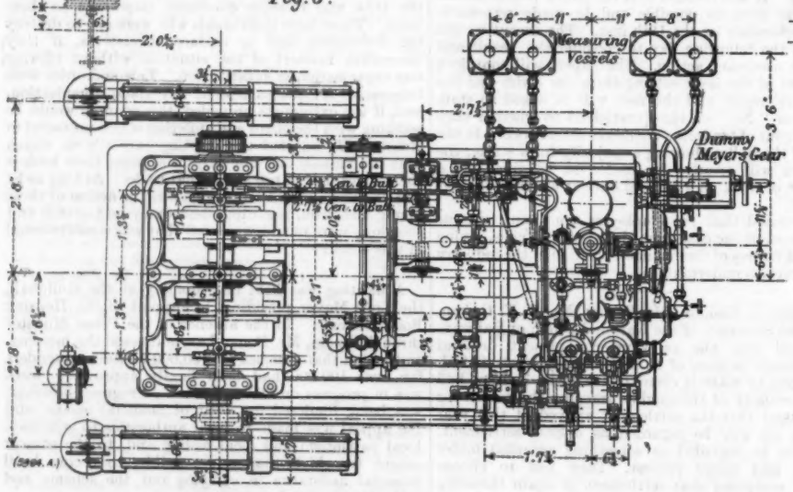


Fig. 3.



BY the generosity of the local coal owners, the University College of South Wales and Monmouthshire has been recently enabled to instal a new experimental engine in their engineering laboratories at Newport-road, Cardiff. The engine, which we illustrate on the present and opposite pages, and on pages 613 and 616, was installed under the supervision of Prof. F. Bacon, M.A., M.I.Mech.E., and was built by Messrs. Marshall, Sons and Co., of Gainsborough, who for many years have made a speciality of steam engines designed for educational purposes. It embodies many features calculated to render it specially serviceable for the training of engineering students where the object is to illustrate, and permit of quantitive investigation respecting, different methods of working.

The engine is a horizontal compound with cylinders arranged side by side. The diameters of the high-pressure and low-pressure cylinders are 5½ in. and 9 in. respectively. The stroke is 12 in. and the cranks are placed at right angles. The normal speed is 150 r.p.m. It is designed so that it can work with the high-pressure cylinder only, the low-pressure cylinder only, or with both cylinders as a compound. Each cylinder is separately jacketed on the barrel and the ends, the supply of steam to and the drains from the ends being separate from those for the barrel. Measuring pots are provided for measuring the water condensed in each jacket. These are seen in the foreground of Fig. 9, page 616.

The high-pressure side (see Fig. 10) is fitted with drop valves for both steam and exhaust. These valves are arranged so that the expansion can be varied by means of the governor. The valves are operated through a layshaft driven from the crankshaft by scroll gearing. The low-pressure side is fitted with an ordinary slide valve with Meyer gear cut-off valves on the back. By means of a hand wheel the cut-off can be varied between one-eighth and five-eighths of the stroke. There is an arrangement fitted to the valve spindles outside the valve chest on which a model diagram of the valves is reproduced, so that it is possible to see exactly how the valves are situated in the steam chest when the engine is at work.

The alteration from high pressure only to compound is effected by means of a valve underneath the cylinders, and when working on the low pressure cylinder only the steam is reduced in pressure by means of a reducing valve before entering the low-pressure cylinder.

Indicator gear is applied to both cylinders. There are two governors; the Proell governor for the automatic arrangement of the high-pressure cylinder, and a Pickering governor operating on the throttle to be used when the engine is working with the low-pressure cylinder-only.

The crankshaft is fitted at both ends with a brake flywheel. Each flywheel is equipped with a set of rope brake tackle, spring balances and weights arranged on the self-compensating principle devised by Lord Kelvin in 1858. The hollow brake rims are water-cooled in each case, supply and drain pipes being fitted to maintain a constant circulation of water when running. One of the flywheel rims has been graduated in degrees, which makes it easy for students to find out for themselves the positions in which the various events of the stroke are timed to occur.

Steam supplied from a water tube boiler is suitably reduced in pressure by a reducing valve, and then enters the engine via a trap on a branch from which a wire-drawing calorimeter is fitted for determining the quality of the steam. Suitable pressure gauges and thermometer pockets are provided for measuring the pressure and temperature of the steam at various points in the course of its passage through the engine. The exhaust steam passes out through the wall into a surface condenser situated in the boiler-house, or it may be diverted into the atmosphere. The condensate discharged by the air pump flows into change-over tanks placed on weighing machines, and suitable means are provided for measuring the rate of flow and rise in temperature of the cooling water.

From the above description it will be seen that the engine illustrated is not only particularly well adapted for experimental purposes, but also provides an example of thoroughly up-to-date design. Junior students will learn how to take diagrams, work out brake and indicated horse-power, study the action of different valve gears and governors, measure steam consumption, and determine efficiencies, &c., under varied conditions of running. Advanced students will be able to make more extensive investigations, such as the influence of cut-off and steam jacketing on economy, influence of cylinder walls, leakage of valves, &c. Such tests will possess enhanced value due to the fact that the engine can be regarded as a complete model of a high-class modern type of drop-valve engine in every respect, which remains as nearly as possible an ordinary commercial engine in all the varied adjustments of which it is capable.

The laboratory in which the new engine has been installed was built under the direction of the late Professor A. C. Elliott, D.Sc., M.I.C.E., as long ago as 1893–5. For many years previous to the war the complete equipment of the laboratory was retarded, due to lack of funds; but from now onwards, progress on a scale worthy of the resources and industrial importance of the district is confidently anticipated. During the war the engineering department of the college successfully undertook a considerable amount of gauge-making and testing work for the Ministry of Munitions. An indirect advantage arising from having adapted the engineering laboratories to deal with this work of national importance was that much machinery of obsolete or obsolescent type had to be disposed of, and this has been, or soon will be, replaced by apparatus and machinery of the latest type. Structural extensions are also being put in hand to meet the rapid increase in the number of students to be accommodated and to provide more adequate facilities for research.

Thanks to the changed attitude of business men and the awakening of public opinion, South Wales is now fully alive to the importance and necessity of providing adequate facilities for higher education in technological subjects. Indeed, there is no part of the country in which the provision and co-ordination of technical education of all grades has recently received more careful consideration than in South Wales and Monmouthshire.

EXPERIMENTAL ENGINE AT UNIVERSITY COLLEGE, CARDIFF.

CONSTRUCTED BY MESSRS. MARSHALL, SONS AND CO., LIMITED, ENGINEERS, GAINSBOROUGH.

(*For Description, see opposite Page.*)

Fig. 4.

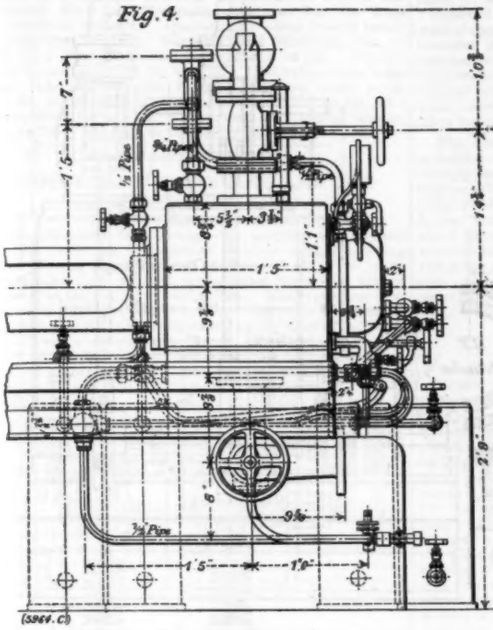
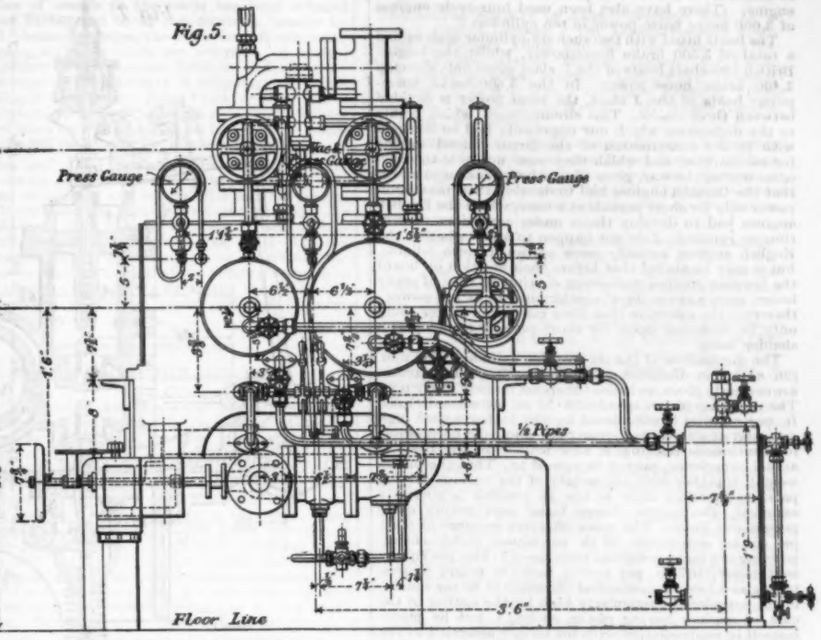


Fig. 5.



GERMAN SUBMARINE DIESEL ENGINES.

In ENGINEERING of June 13, 1919, p. 763, we published an article descriptive of German submarine Diesel-engine design and construction, indicating from an examination of their engines the policy followed by our late enemies and deducing the leading considerations that seemed to our contributor to have underlain the methods reviewed.

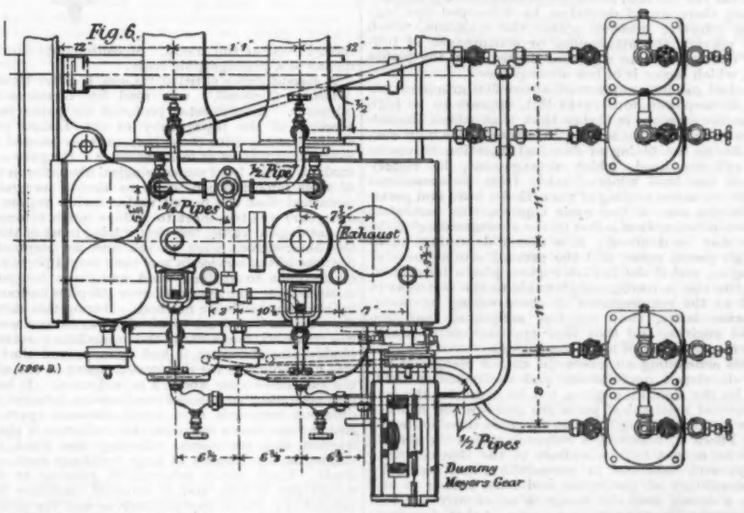
We publish now a reply from the German journal, the *Schiffbau*, of February 11, 1920, giving in full those portions that serve to throw further light on this subject. This article will no doubt be of considerable interest to British designers and constructors, as giving some of the fruits of German experience and findings of experiment and sea-going service.

The handing over of our submarines to the British has enabled them to become thoroughly conversant with our latest types of boats and their mechanical equipment. In ENGINEERING there has been published a notable article entitled "German Submarine Diesel Engines," notable especially because the author, who unfortunately is not named, but who apparently is quite an expert, seems to endeavour to do justice to the high value of German technics as illustrated in the case of the submarine engines but notable also since he does not limit himself to a description of the types, but follows up successively the reasons for their selection.

The conclusions drawn at the time, following upon various failures in the early stages of development, that the Nuremberg stepped-piston type of engine was not very suitable for submarine propulsion proved later to be incorrect. Constructions which embodied the results of experience gained, have further established the suitability of these engines for this duty and have also given a fuel consumption little in excess of that of the Augsburg four-cycle engine. In the case of the two-cycle stepped-piston type there remains, generally speaking, only the unfavourable circumstance that the removal of the pistons in the boat is surrounded with great difficulties, and also the disadvantage of having the pressure upon the main bearing always in the one direction.

The author's statement to the effect that also in Germany, before the war, the two-cycle engine was decidedly preferred, whilst during the war Germany almost exclusively resorted to the four-cycle principle requires some modification. The four-cycle engine was preferred in Germany before the war, at least so far as engines for warship purposes were concerned, although during the war there were at one period many more boats equipped with two-cycle than with four-cycle engines. This situation is due to the fact that before the war foreign Governments had ordered from German firms a considerable number of two-cycle engines, and these engines, owing to war requirements, were utilised in the German Navy. But notwithstanding this, the four-cycle engine was preferred in Germany for the simple reason that it involved fewer difficulties of construction, it was more thoroughly developed and hence more reliable, and from the point of view of its fuel consumption it was then well known to be superior to the two-cycle engine.

Fig. 6.



The German Navy, following the sound maxim of proving all things and "retaining the best," had indeed given due attention to the two-cycle engine, mainly in the hope of building of this type, for equal duty, smaller and lighter engines. This expectation was not fulfilled. The scavenging pump required for the two-cycle engine led to the absorption of about as much space and weight as was saved by the smaller dimensions of the working cylinders. The dimensions are not so very much smaller than were those of the four-cycle engine cylinders; the piston speed also, and, to a greater extent still, the mean pressure, must be maintained with two-cycle engines lower than in the four-cycle engine. Another advantage of the two-cycle engine, namely, the fact that reversing is of simpler design and construction, cannot be gainsaid, and this advantage increases in importance with increase in engine power.

The reason why German submarine engine construction during the war has been directed almost exclusively to the four-cycle type is therefore less to be sought in the properties which are inseparable from each type than in the state of development in which they stood at the time. Since the reliability of the two-cycle engines had not reached the point that was aimed at, it was quite obvious that in the pressure of war time no further experiments could be engaged upon even though their results could be viewed in even the most hopeful light; on the other hand, the best designs which were then and there available were resorted to. To lay down that the two-cycle in itself was less satisfactory and had consequently to be set aside is beside the point, and is not the fact. I am fully convinced that had the war taken a different turn, the German Naval Authorities would not have failed to give due attention to the development of the two-cycle type also for submarines, and for engines of greater power she would even have been compelled to do so.

A side remark points to the view of the English author that the development in Germany might have been different if, at the outbreak of war, port scavenging had been further developed. For experiment in this line there was, he asserts, but few possibilities during hostilities. One can but agree with this, for, in effect the advantages of the two-cycle engines appear in their true light only when scavenging by means of valves disappear. The practical application of port scavenging is certainly not simple, and it requires great experience if smokeless combustion and low fuel consumption are desired, and even at the present time this question is not solved in all particulars, notwithstanding the great progress recently made following upon experiments carried out on systematic and scientific lines.

The author, after shortly referring to the main points which differentiate the Germania from the M.A.N. engine, and stating the opinion, which does not hold good, that

for the head of the working cylinder manganese bronze has proved itself to be the most suitable material (as a matter of fact the experiments, carried out with a manganese-nickel-bronze cover, resorted to provisionally, cannot be said to have been satisfactory), he enters into a description of the largest M.A.N. type, with which he appears to have been better acquainted, namely, the so-called 1,750 brake horse-power four-cycle six-cylinder engine. (There have also been used four-cycle engines of 3,000 brake horse-power in ten cylinders.)

The boats fitted with two such six-cylinder engines had a total of 3,500 brake horse-power, whilst the largest British two-shaft boats of the L class could only develop 2,400 brake horse-power. In the 3,600-brake horse-power boats of the J class, the total power is divided between three shafts. This circumstance, which points to the difficulties which our opponents had to contend with in the construction of the larger Diesel engine for submarines, and which they were not able to overcome during the war, gives the author occasion to assert that the German engines had to develop their maximum power only for short periods at a time, whilst the English engines had to develop theirs under conditions of continuous running. I do not happen to know whether the English engines actually were so much more reliable, but it may be stated that before their erection on board the German engines underwent continuous runs of many hours, even a seven days' continuous run at full power; therefore the assertion that their maximum power could only be reckoned upon for short periods rests upon a slender basis.

The dimensions of the six working cylinders, 530 mm. (20·84 in.) in diameter and 530 mm. (20·84 in.) stroke, are correctly given, as is also the speed, namely, 380 r.p.m. The resulting piston speed of 6·71 m. per second (1,320 ft. per minute) is considered by the author a very high one, and at all events higher than would be permissible for continuous running, a view which, on the basis of actual experience, cannot be agreed to. That the piston weight, together with the weight of the various driving parts is therefore kept as low as possible is correctly assumed, the inertia forces being kept within quite permissible limits. The mean effective pressure of 6 kg. per square centimetre (85 lb. per square inch)—corresponding to a mean indicated pressure of 7·5 kg. per square centimeter (107 lb. per square inch) in round figures, taking as a basis a mechanical efficiency of 80 per cent.—is not considered particularly high by the author in the case of engines having piston cooling; but he places himself in contradiction with his former assertion to the effect that the full load could not be continuously carried, for then there would doubtless be developed too high a mean effective pressure within the cylinders, which would prevent the attainment or continuance of full-power development to a greater degree than the piston speed, which factor is of less consequence.

The fuel oil consumption of about 200 grammes per brake horse-power hour (0·44 lb.), appears to be high and, in his opinion, is higher than that which English engines gave in actual service. He traces this high consumption to the fitting of two fuel injection valves in each cylinder head, which arrangement, he rightly assumes, has been adopted solely from constructional grounds—a better cooling of the cylinder head and parts. That in the case of four-cycle engines, this somewhat high fuel consumption is due to the arrangements of the valves may be doubted; it is rather dependant upon the high piston speed and the general compactness of the engine, and if the British engines give a lower consumption, this is readily attributable to the fact that in regard to the requirements of space saving on board submarine boats, they are less adaptable than the German engines, and that they approach more nearly to the requirements of land installations.

In his concluding sentences the author recognises the highly-developed manufacture and workmanship evidenced by the German engines, but he expresses the fear that several mechanical parts are perhaps too delicate for the rough handling likely to be given them on board ship. There is, however, a reproach which the author thinks he cannot fail to address to the German firm, namely, with reference to accessibility, and especially the accessibility of the piping and other parts; to him this is a defect, and the design is apparently not well thought out. The impression is gathered that, for every trouble that occurs, the unshipping of parts of the engines and their refit in the shop have to be reckoned upon, whilst in the instance of British engines more consideration has been given to the possibility of executing repairs on board. This disadvantage, so far as it really exists, is accounted for by the compactness of the German type of engine, due to the necessity of turning to the best advantage possible the smallest space available.

Taking it all in all, German Diesel engineers can be thoroughly satisfied with this expert criticism of British origin.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 21st ult., at the Society's Rooms, 70, Victoria-street, Westminster, Mr. R. H. Hooker, M.A., president, in the chair.

A description of the *Night Sky Recorder* recently brought into use at the Royal Observatory, Greenwich, was given. The object of the instrument is to supplement the daily sunshine record in so far as it gives an indication of the amount of cloud. The instrument consists of a small camera in a fixed position pointing to the pole of the heavens. The lens is a single component of a doublet of 8 in. focal length and 0·4 in. aperture, working at *f*/20. It is found that the aperture in conjunction with plates of "ordinary" speed will give a good record even at full moon. Measurements are made by means of a photographic scale.

A second paper entitled "*Local Weather Conditions at Mullion, Cornwall*," was read by Lieutenant N. L. Silvester. Mr. Silvester prefaced his paper by a brief account of the topography of the Lizard peninsula, dealing mainly with those features that seemed to act as controlling factors of local weather. He gave a detailed analysis of the local meteorological elements in the order of their importance relative to airship navigation, but remarked that the period under review (approximately one year) was too short to deduce much information of climatological value, but that during most of this period, the observations were as full and as frequent as the changes of the service in war time would permit. Ratios of gradient to surface wind had been computed and analysed from the results of over 400 pilot balloon ascents by the one-theodolite method. During this short period the weather hut, from which all observations were made, was removed from a site in the immediate precincts of the airship station—after it had been proved that the site was unfavourable for the measurement of the wind near the surface—to one about a mile distant. It had therefore been possible to make comparisons between two very different exposures at a small distance apart. These had at least shown unmistakable evidence of the marked friction and turbulence affecting the wind near the surface in the vicinity of large buildings such as airship sheds. Much useful information relating to the local occurrence of fogs and of unusual visibility had been tabulated; whilst another feature was the collection in tabular form of local signs of approaching bad weather, which should prove of value to the local forecaster.

Mr. J. E. Clark gave an account of the Surrey hail-storm of July 16, 1918. This storm differed from other similar British visitations by the fortunate absence of much wind and by coming after midnight. The track of serious damage rarely exceeded a ½-mile width and was 16½ miles long, the hail beginning at 1.55 a.m. west of Holmwood station and ending near North Bromley Station, 22 miles to the north-east, at about 2.30 a.m. (true time). Rain and hail ceased sharply beyond the south-east margin, near which the fall was heaviest. At Purley it was 1·37 in., compared with 1·03 in. 600 yards north-west; these amounts falling, respectively, in 11 minutes and 10 minutes. The north-western margin varied much more; hail damage, hail and heavy rain gradually lessening the hail, ceasing from 1½ miles to nearly 5 miles north-west of the other margin. Vivid, almost incessant lightning accompanied the hail, the noise of the latter, however, rendered the thunder inaudible. About 25 per cent. of the hail consisted of jagged chunks of ice, some up to 2 in. or 3 in. long. One piece, 6 hours or 7 hours later, still measured 2½ in. by 2 in. by 1½ in., and much larger ones were reported. Greenhouse roofs and some windows were smashed and crops destroyed, in places reduced to pulp. The total damage amounted to at least 10,000*l*. The associated thunderstorm over south-east England was considered in the paper; also the temperature, pressure, wind and upper air conditions.

DETAILS OF EXPERIMENTAL ENGINE.

CONSTRUCTED BY MESSRS. MARSHALL, SONS AND CO., LTD., ENGINEERS, GAINSBOROUGH.

(*For Description, see Page* 612.)

Fig. 7.

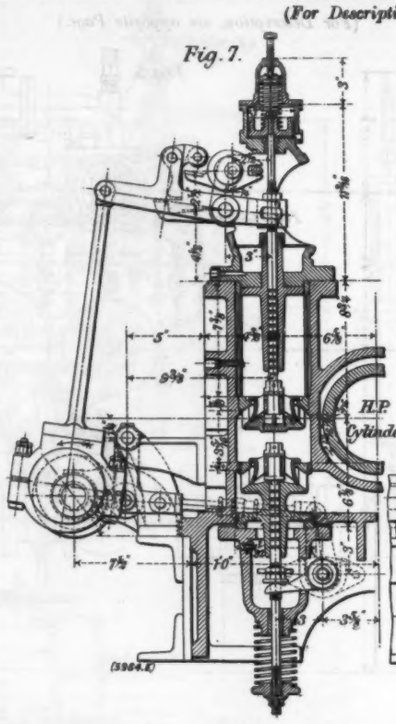
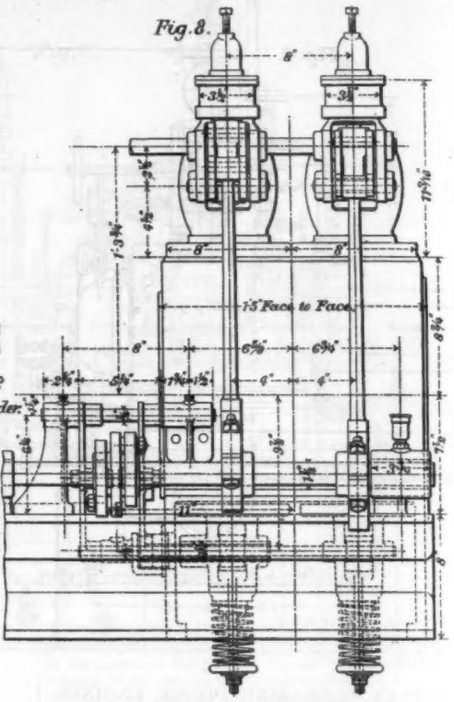


Fig. 8.



NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

German Push.—Evidence has come to hand during the past week of German endeavour to compete with South Yorkshire makers of motor lorries for commercial purposes. Through an agent in the Midlands, a limited number of motor lorries are being offered at prices substantially lower than those quoted for the local product. These prices are inclusive of the cost of delivery. The offer so far has not been entertained by local makers or merchants.

Railway Delay.—Despite the widespread appeal posted on all traffic depôts for the early release of wagons and the expediting of traffic, numerous complaints continue to be received at the headquarters of the South Yorkshire Manufacturers' Association of damage to trade through railways delay. In some cases makers of finished steel, it is reported, have been compelled to restrict output, because their stocking facilities are congested, and it is impossible to secure reasonable despatch of current production. A similar disability impedes work at the blast furnaces, where a considerable tonnage of pig-iron is stocked awaiting the arrival of trucks for delivery.

Iron and Steel.—The opinion that business in engineering products is slowing down owing to the continued inflation of prices at home and the adverse condition of foreign exchanges has gained further support by the developments of the past week. Orders from Continental sources for steel and machinery are distinctly fewer, and though certain sections of the Sheffield steel trade are exceptionally busy, there is no doubt that the heavy departments are in for a much quieter time than has been experienced during the past four months. Apart from the European demand, however, business with the United States, South America, India and South Africa continues of a healthy character. An immediate market is found for all the textile machinery that can be produced, and makers of mining and agricultural requisites have some difficulty in keeping pace with requirements, both on home and export account. The engineering demand for files has been somewhat retarded by the release of substantial stocks, but otherwise export needs are on a large scale. The improvement in the trade in special steels with the United States is fully maintained. Local quotations for delivery across the Atlantic, compare very favourably with those of the United States makers of tungsten material. In the lighter trades, work continues generally at high pressure. In order to secure more equal distribution of orders and to minimise working costs, a number of amalgamations between small firms chiefly employed in the manufacture of hand tools and implement parts, have been completed. There is no indication of any immediate decline in prices of raw and semi-finished materials. Finished iron is very difficult to obtain at the revised rates. A further advance of 1*l*. per ton on the quotation of 28*l*. 10*s*. for Crown bars is forecasted.

South Yorkshire Coal Trade.—The acute shortage of coke is having a serious effect upon the output of steel. Many of the local furnaces are running short time, and

in a few cases work is reported to have been suspended. On the open market there is very little free coal of any description. Steam hards are in great demand by industrial consumers of all classes. Business is restricted to day-to-day supplies. Reserves at gas works have somewhat improved, but the safety margin has not yet been reached. Contractors are taking the full output of cobbles, nuts, and slacks, chiefly for inland delivery. There is a marked shortage of household fuel in the outlying districts. Merchants are carrying on with considerable difficulty. Quotations :—Best branch hand-picked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.*; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 24*s.* to 25*s.*; nutty, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—No surprise was created by the Cleveland ironmasters at their weekly meeting again leaving pig-iron prices unchanged, the view being taken that they will not revise rates until it is known what is to happen as to fuel values. Meantime any iron contracts that are made contain the protective clause that the sale is at the price ruling at the time of delivery. For home consumption, No. 1 Cleveland pig-iron is 212*s.* 6*d.*, and No. 3 and the commoner kinds are 200*s.*; and for shipment to France, Belgium and Italy, No. 1 is 217*s.* 6*d.* and No. 3 and the lower qualities are 205*s.*

Hematite Iron.—East Coast hematite is less scarce than it has been, but while the large home demand is now rather more than met, the quantities available for sale abroad are only small. To home customers No. 1 is 262*s.* 6*d.* and mixed Nos. are 260*s.*, and for despatch to France, Belgium and Italy No. 1 is 267*s.* 6*d.* and mixed Nos. are 265*s.*

Coke.—Local consumers of coke report supplies now coming forward satisfactorily, and with home needs adequately dealt with a little coke is once more being liberated for export. For home purposes medium blast-furnace kind is 55*s.* 6*d.* at the ovens, and low phosphorus sort 58*s.* at the ovens. For export gas-house coke is 130*s.* to 132*s.* 6*d.*

Manufactured Iron and Steel.—Great firmness characterises finished iron and steel, demand for which is unabated. Manufacturers are so overwhelmed with work, and so much in arrears with deliveries that they cannot entertain new business on anything like an extensive scale. The heavy stocks of steel which are sold to customers who are clamouring for supplies cannot be distributed because of lack of railway facilities. The following are among the principal market quotations :—Common iron bars, 28*l.*; marked bars, 30*l.*; rivets, 36*l.*; steel ship, bridge and tank plates, 23*l.* 10*s.*; steel angles, 22*l.* 10*s.*; steel boiler plates, 28*l.* 10*s.*; steel joists, 22*l.* 10*s.*; steel strip, 27*l.* 10*s.*; steel hoops, 27*l.* 10*s.*; packing steel (parallel), 18*l.* 5*s.*; packing steel (tapered), 22*l.* 10*s.*; soft steel billets, 22*l.* 10*s.*; hard steel billets, 23*l.* 10*s.*; heavy sections of steel rails, 23*l.*; fish plates and sleepers, 28*l.*; black sheets, 45*l.*; and galvanised corrugated sheets, 56*l.*

Shipments of Iron and Steel.—Loadings of iron and steel at the port of Middlesbrough during April totalled 89,785 tons, of which 51,840 tons were pig-iron, 2,424 tons manufactured iron, and 35,521 tons steel. Italy received 13,381 tons of pig-iron; Belgium, 10,809 tons; Scotland, 8,520 tons; Wales, 6,095 tons; Japan, 4,728 tons; and France, 1,977 tons. India with an import of 919 tons was the largest customer for manufactured iron, and the principal customers for steel were: Japan, 8,233 tons; India, 7,468 tons; Portuguese East Africa, 2,318 tons; and Cape Colony, 2,270 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—A loss of one day's output in connection with the May Day labour demonstrations, and the consequent pressure for home supplies to make up for this reduction in production, has made export business practically impossible owing to heavy inland allocations and a resultant diminution in the quantity available for shipment. The outlook is, however, more hopeful, as the miners have reversed their decision of a general strike in connection with the Nine-Mile Point minimum wage dispute, and the men directly affected have also returned to work. The threat of a national coal strike is also removed, and thus it is anticipated that there will be a relaxation in the home demand and a corresponding increase in the quantity available for shipment. In the past week foreign exports from South Wales totalled 335,613 tons, of which 186,934 tons, or 56 per cent., were supplied to France, 58,400 tons to Italy, 17,048 tons to South America, 7,599 tons to Spain, 10,480 tons to Portugal, 51,903 tons to British coaling depots and 3,429 tons to other countries. With a return to normal conditions outputs should also increase and, though releases are still sparingly granted, there is every hope of an improvement in the early future, though the proximity of the Whitsun holidays may delay any substantial increase in foreign exports. Collieries in practically all cases are full up with allocations and contract commitments, and buyers experience much difficulty in securing even small parcels. Prices in the circumstances are firm, and for the better quality large 115*s.* to 117*s.* 6*d.* is readily paid with 110*s.* to 115*s.* ruling for other descriptions. Throughs are round 107*s.* 6*d.* and smalls from 92*s.* 6*d.* to 97*s.* 6*d.*, according to quality. Coke exports are at a standstill because of the continuance of the export embargo, and patent fuel is practically unobtainable as most makers are booked up till the middle of the year and for the small available parcels 125*s.* to 130*s.* is forthcoming. Though the number of vessels in the roads has been reduced from 57 on Friday last to 36 this morning, mainly by "directed" ballast voyages, the docks are still congested with shipping, and long waits are common. A typical instance is that of the steamer Lubeck, of 2,934 gross register, owned by the Ministry of Shipping, which has been waiting in Cardiff since April 7 last for about 2,000 tons of bunkers, to proceed to South America in ballast. This vessel has a crew of about 84 on board, all of whom have been on full pay during the whole of the time.

The Iron and Steel Trades.—Quiet conditions have pervaded the tin-plate market during the past week. The inquiry has diminished and buyers offer 68*s.* for prompt delivery of the basis box, but as most manufacturers are fully booked up they are not disposed to sell at this figure, and are holding for 71*s.* to 74*s.* f.o.t. Tin and sheet bars are also a quiet market, as sellers are not anxious to do business in view of the pending increase in the price of coal and bars are nominally round 30*l.* per ton. Galvanised sheets are round 56*l.* for 24-gauge corrugated sheets.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Activity is still general in the steel trade of Scotland, and all establishments are as busy as they can possibly be. Raw material is scarce, and the irregularity of deliveries has also a tendency to delay production with the result that outputs are not nearly as large as they might be. The shorter working week, while perhaps good from the point of view of the manual worker, is not, at the present time, a very good thing for the world at large owing to the great shortage of nearly all manufactured commodities resulting from the war years 1914–18. The steel makers like those in the allied trades, have been confining their outputs almost wholly to the home trade, and are still doing so, and this has reduced the export business to a very small percentage. It has generally been anticipated that in a month or two there would surely be something over for shipment, but each month seems to make that more impossible and to remove the date for opening up foreign business much further away than ever. Even rising prices have failed utterly to put a check on buying, and each week the pressure for deliveries is as great as during the previous one. The steadily rising cost of production is once again the cause of another increase in prices, and the Scottish steel-makers advanced their quotations for plates and angles as from Monday of this week, and the new rates, subject of course to certain extras for delivery, are now as follow: Ship plates, ¼ in. and up, 26*l.* per ton, net; under ¼ in. to $\frac{7}{16}$ in., 31*l.* 10*s.* per ton, net; under $\frac{7}{16}$ in. to ½ in., 33*l.* per ton, net; angles, &c., 25*l.* 10*s.* per ton, net; boiler plates, 30*l.* 10*s.* per ton, net. These new prices do not yet spell finality as they may shortly have to be raised again if the Coal Controller authorises an increase in the price of fuel. The position in the black sheet trade is very similar to that of plates and sections, and advancing costs have necessitated another increase in quotations. The basis prices now arranged by the Scottish Black Sheet Makers' Association are as follow: Steel sheets, ½ in. and thicker, 38*l.* 10*s.* per ton; under ½ in. to 12-gauge, 39*l.* per ton; under 12-gauge to 16-gauge, 41*l.* per ton; under 16-gauge to 20-gauge, 42*l.* 10*s.* per ton; under 20-gauge to 24-gauge, 44*l.* per ton. These new rates came into force to-day (Wednesday), and have been found necessary owing to the abnormally high prices ruling for sheet bars. All the works are going at top speed and will continue so for a long time as the number of orders booked represents a very large tonnage.

Malleable Iron Trade.—No change of any moment falls to be recorded in connection with the malleable iron trade of the West of Scotland this week. The various establishments are all exceedingly busy and outputs are going quickly into consumption, with the result that buyers keep "knocking at the door" of makers and are constantly inquiring for further deliveries. With "crown" bars at the high level of 28*l.* per ton one would have thought that the demand might have eased off slightly, but that is not the case, and buyers are still eager for supplies. How long the present state of affairs can last with prices of everything so abnormally high it is difficult to forecast. The export trade is not heavy.

Scotch Shipbuilding.—The past month has been an exceptionally good one in the Scotch shipbuilding industry, and the output amounts to the large total of 34 vessels of 102,468 tons, made up as follows :—

	Vessels.	Tons.
The Clyde...	19	85,008
The Forth	6	7,780
The Tay	1	7,620
The Dee and Moray Firth	8	2,060
Total	34	102,468

A most interesting fact with reference to the above figures is that the vessel launched on the Tay is the largest ever built on the East Coast of Scotland. It was the s.s. Machaon, 7,620 tons, and 4,800 i.h.p., built and engined by the Caledon Shipbuilding and Engineering Company, Limited, Dundee, for the Ocean Steamship Company, Limited, Liverpool. The Clyde total is also interesting because it is the third highest tonnage on record for the month of April, and it is only about 13,000 tons less than the total for the other three months of this year. The output for the year to date is 52 vessels, making 182,962 tons, which total has only twice been bettered for the first four months of any previous year. These two occasions were 1913 (237,161 tons) and 1912 (199,104 tons). Of course the output for this year is a long way behind the record year of 1913, and a very large monthly total will be necessary if that year is to be left behind. The shipbuilders have the orders, but it is the shortage of materials of nearly all kinds which is keeping back production, and if ship plates were only a little more plentiful the present year might almost yet create a record which would take a lot of beating.

Scotch Pig-Iron Trade.—There is continued activity in the pig-iron trade of Scotland, and the demand is very heavy for all kinds of iron, which is no more plentiful now than it has been for months back. In fact, this state is perhaps worse, as the great scarcity is more general all round and prices are very firm. No. 1 foundry iron is quoted round 14*l.* 15*s.* per ton, for home consumption, and No. 3 is round 13*l.* 10*s.* to 13*l.* 15*s.* per ton, while for export lots the prices named are about 16*l.* 5*s.*, and 15*l.* 5*s.* per ton respectively, but the difficulty is to obtain any iron for shipment. Hematite is in very large demand by the steel makers, who cannot get sufficient for their requirements. The scarcity is serious, and is not being taken lightly. Prices for this month have been raised by 15*s.* per ton, making the current rate now 13*l.* 15*s.* per ton, net, delivered at works. As in the case of steel and bar iron, &c., should fuel be increased by the Coal Controller another rise in prices may be found necessary.

NOTICES OF MEETINGS.

THE SURVEYORS' INSTITUTION.—Monday, May 10, when a paper will be read, entitled "Rent Problems," by Mr. Sydney A. Smith (Fellow). The chair will be taken at 8 p.m.

THE ROYAL SOCIETY OF ARTS.—Monday, May 10, at 8 p.m.: Cantor Lecture, "The Decoration and Architecture of Robert Adam and Sir John Sloane, 1758–1837," by Mr. Arthur Thomas Bolton, F.R.I.B.A., F.S.A., Curator, Soane Museum (Lecture II). Wednesday, May 12, at 4.30 p.m.: Ordinary Meeting, "Rolls of Honour," by Mr. Grailey Hewitt. Mr. Halsey Ricardo, F.R.I.B.A., will preside.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, May 11, at 8.15 p.m., at the Royal Society of Arts, John-street, Adelphi, London, when an account of "Recent Developments in Portable Types of Cinema Outfits" will be delivered by Captain J. W. Barber, C.B.E.

THE ROYAL AERONAUTICAL SOCIETY.—Wednesday, May 12, at 8 p.m., at the Royal Society of Arts, John-street, Adelphi, London, W.C.2. A paper entitled "Notes on Flying Boats" will be read by Major Linton Hope. The chair will be taken by Dr. L. Bairstow.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 13, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. "Permanent Magnets in Theory and Practice," by Mr. S. Evershed, Member.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Friday, May 14, at 7.30 p.m., at the Technical Institute, Coventry, when a paper on "Cast-Iron in Relation to the Automobile Industry" will be read by Mr. J. E. Hurst.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 14, at 9 p.m., a discourse will be delivered by Professor Karl Pearson, F.R.S. The subject is "Sidelights on the Evolution of Man." Afternoon Lectures at 3 p.m.: Tuesday, May 11, Professor Arthur Keith, M.D., LL.D., F.R.S., M.R.I., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology —The Invaders of England" (Lecture III); Thursday, May 13, Mr. A. P. Graves, M.A., F.R.S.L., on "Welsh and Irish Folk Song" (with musical illustrations) (Lecture I); Saturday, May 15, Mr. Frederic Harrison, D.C.L., D.Litt., LL.D., on "(1) A Philosophical Synthesis as Proposed by Auguste Comte."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 14, at 7.30 p.m., at 39, Victoria-street, S.W. 1. "Discussion and Business Aspect of the Peace Treaty," Opener, the Hon. H. Fletcher Moulton.

THE IRON AND STEEL INSTITUTE.—Friday, May 14, at 3 p.m., Adjourned Meeting at the Mappin Hall of Sheffield University. The following is a list of the papers which it is expected will be subinitted: (13) Mr. J. H. Andrew, Mr. J. E. Rippon, Mr. C. P. Miller and Mr. A. Wragg, "Effect of Initial Temperature upon the Physical Properties of Steel"; (14) Mr. C. A. Edwards, Mr. H. Sutton and Mr. G. Oishi, "The Properties of Iron-Chromium-Carbon Steels" (Part I, "Thermal Analysis") Mr. C. A. Edwards and Mr. A. L. Norbury, "The Properties of Iron-Chromium-Carbon Steels" (Part II, "Effect of Heat Treatment on Electrical Resistivity"; (15) Mr. K. Honda and Mr. T. Murakami, "On the Structural Constitution, Hardening and Tempering of High-Speed Steel containing Chromium and Tungsten"; (16) Mr. J. H. G. Monypenny, "The Structure of some Chromium Steels"; (17) Mr. A. L. Norbury, "The Effect of Various Elements on the Electrical Resistivity of Iron"; (18) Mr. F. Rogers, "Brittleness of Nickel-Chrome and other Steels" (Part II).

EXPERIMENTAL ENGINE AT UNIVERSITY COLLEGE, CARDIFF.

CONSTRUCTED BY MESSRS. MARSHALL, SONS AND CO., LIMITED, ENGINEERS, GAINSBOROUGH.

(*For Description, see Page* 612.)

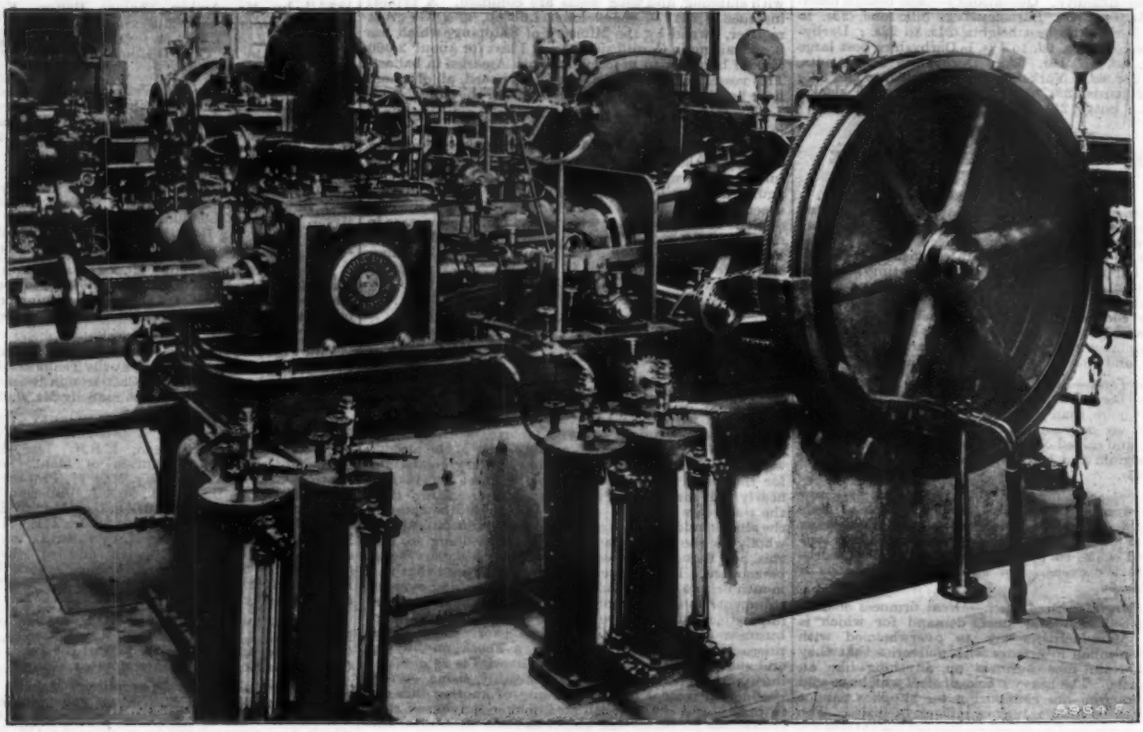


Fig. 9.

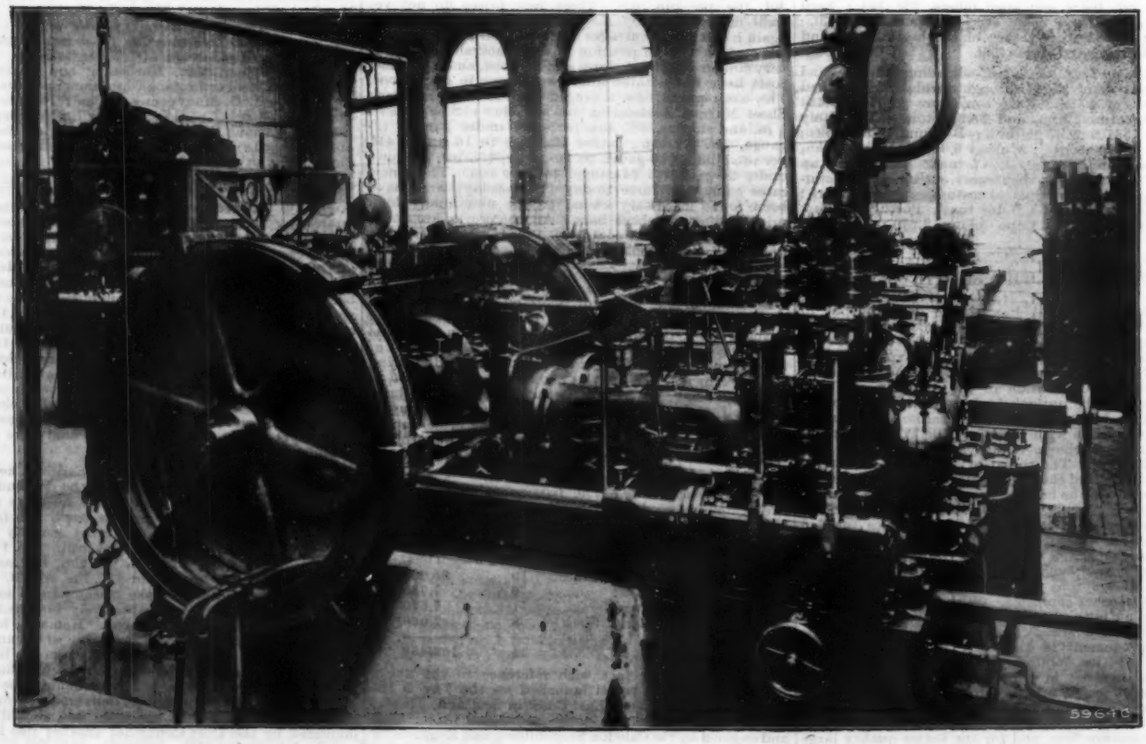


Fig. 10.

ARMSTRONG SHIPYARD; THE

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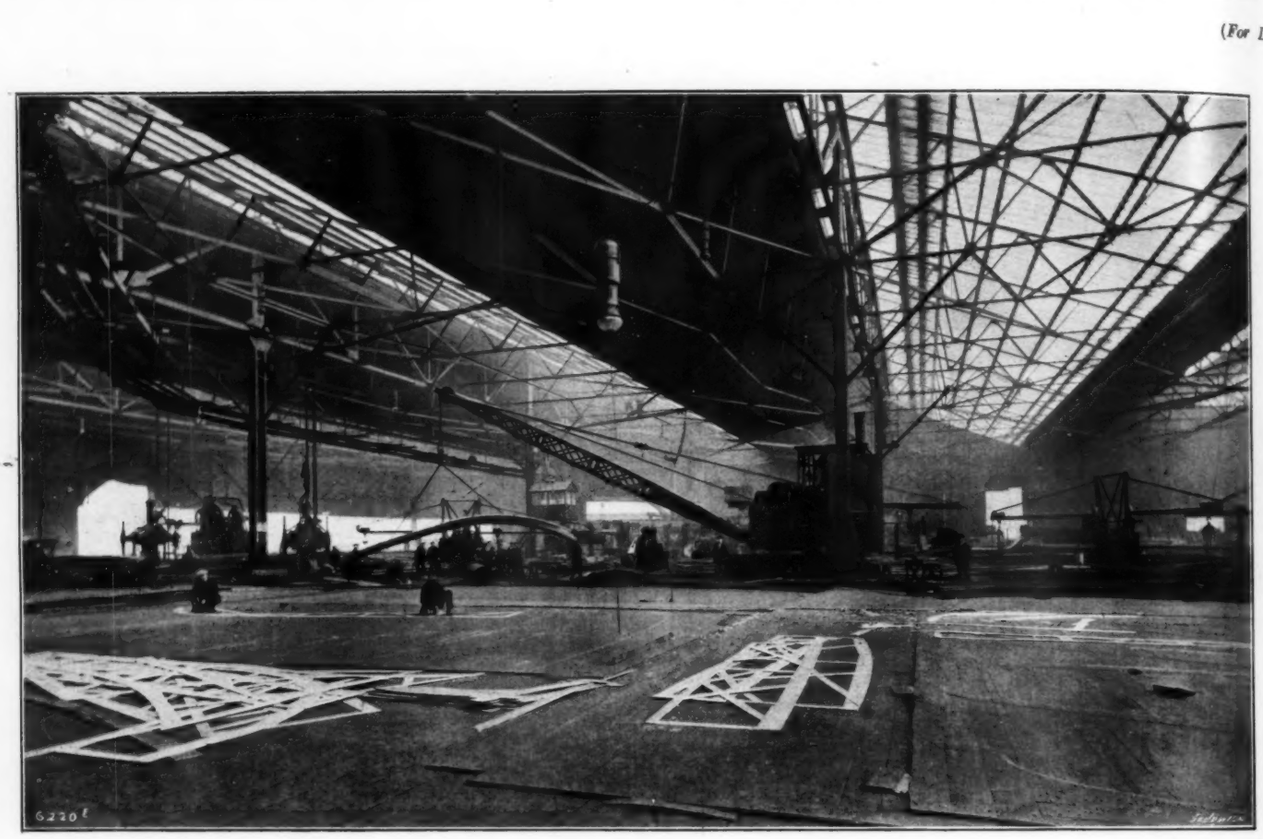

Fig. 136. Scrieve Boards in Frame Shed.

Fig. 137. Furnaces and Bending Blocks in Frame Shed.

HE ME SHED AND FITTING SHOP.

(For Desc... Page 601.)

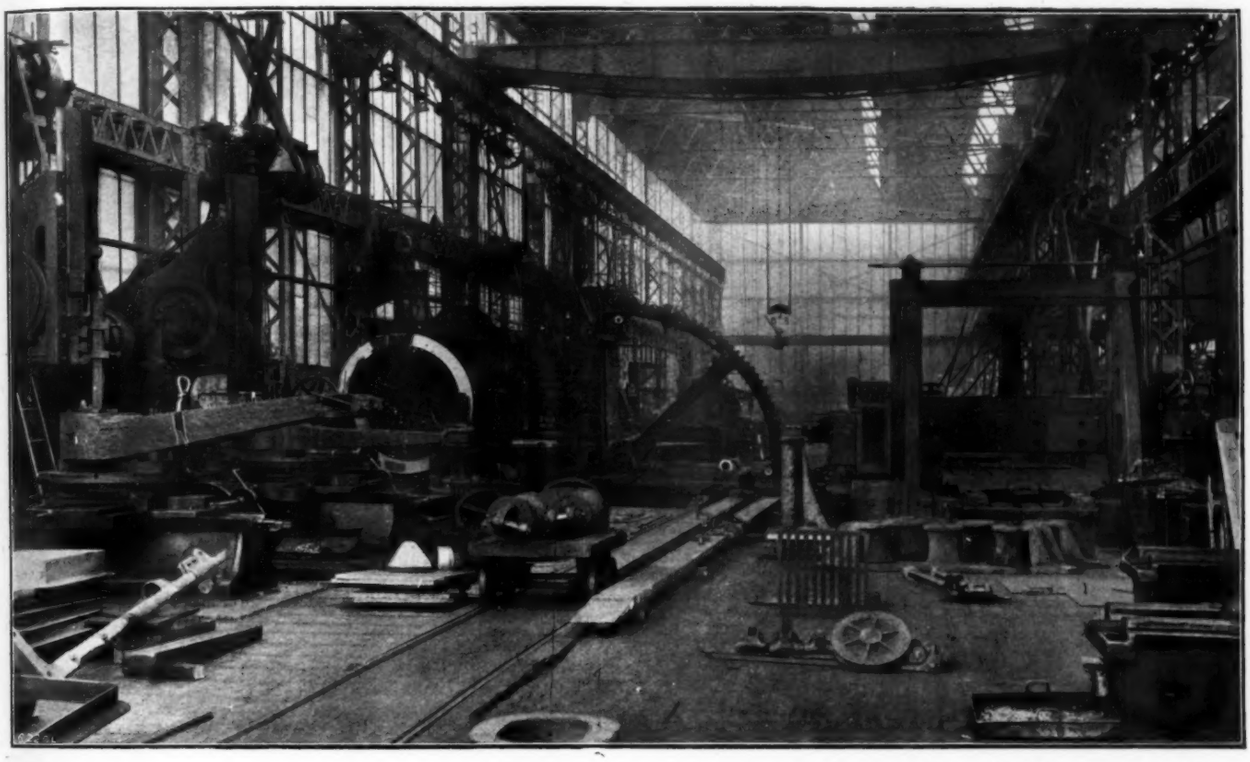

Fig. 138. View of Main Bay in Fitting Shop.

Fig. 139. View of One of the 28 Ft. Bays in Fitting Shop.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. So long as postal rates remain as at present there will be no increase in the price of copies sent by inland post, which will continue at 1s. 2d. post free.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 615.

ENGINEERING.

FRIDAY, MAY 7, 1920.

THE GENERAL TREND OF DIESEL MARINE MACHINERY.

ENGINEERS who are actively engaged on the construction of any one particular type of machinery, are liable to become so engrossed in their own limited sphere of activities and in meeting the problems and questions with which they are immediately confronted, that they do not make the opportunities, or spare the time, to take cognizance of and to review periodically the broad trend of affairs in the same line of work the world over. It is, however, necessary in order to reach or to maintain a high position in any branch of industry, that full recognition should be given to what is being accomplished elsewhere, and to learn as much as possible from successes or failures of similar products in markets other than those catered for by home engineers.

There is, at the present time, no problem concerning the minds of our marine engineers to a greater extent than that of the application of the Diesel oil engine to marine propulsion. The development of this prime mover is international, and whilst economic conditions principally, together with a few other subsidiary factors, have contributed hitherto to a larger and broader activity of construction for both land and marine purposes abroad than at home, events are now rapidly marching to the desirable position where the technical and commercial competition between the various maritime and shipbuilding countries will be extremely keen.

It is, therefore, now opportune to review briefly and on general lines the characteristics of the types of engine which are on order and under construction the world over. Statistics, so far as they are available and without any data as to German building, show that in the field of ships of greater deadweight capacity than 2,000 tons, considerably more than 150 are on order, and in course of construction at the present time, and are destined to be fitted with marine Diesel engines. In some cases the ship is being built in one country whilst the engines are to be supplied from another, but since relatively few novelties in the shipbuilding sense are presented by these vessels, this review will be entirely concerned with considerations of the propelling machinery. The Diesel motors for these ships are being supplied by at least seven countries, and in respect of numbers of sets of machinery the order of importance is approximately the following: Denmark, United States of America, Britain, Sweden, Holland, France, Italy and Switzerland. Since the numbers upon which this sequence is based include definite future as well as present construction, those countries which early on took a leading part in the marine Diesel world, can naturally obtain and can safely book orders much further ahead than can be or would be desirable in the case of the countries where a later start was made or the interference of the war had effect. With this proviso, however, the statement of the order is significant, and probably indicates quite approximately the extent of development of the Diesel marine engine in the various countries named.

The position of Britain cannot be regarded with complacency. In justification, if not in full measure, we can plead the effects of the war which seriously suspended construction other than of a thoroughly standardised nature in order rapidly to give results with the minimum of expenditure of workmanship and materials. In such circumstances the steam engine naturally was the prime mover upon which to concentrate. Undoubtedly, however, at the present time our position is rapidly being improved, and there are other factors later to be touched upon which can also be quoted in mitigation. It will be noted that of the first five countries in the above list three were neutrals in the war, and in the case of the United States of America, the effects of the war were only partially felt and at a much later date than in the United Kingdom.

A review of the type of engine being constructed goes to show that the simple single-acting, four-stroke cycle engine is even more favoured to-day in connection with marine Diesel work than it has ever been in the past history of this type of mercantile construction, and of the vessels building only some 16 per cent. are to be fitted with engines of the two-stroke cycle type.

It will readily be conceded that this figure is quite remarkable. If numbers of engines were taken, the percentage of two-stroke cycle construction would probably even be considerably lower, since almost half of the two-cycle engined ships are single-screw, whereas 90 per cent. of the four-stroke cycle machinery is of the twin-screw variety. In the early days of the introduction of the oil engine to marine work, the two-stroke cycle was generally the favoured system. The same success as with the four-stroke cycle engine did not meet these initial efforts, and these failures are, in a measure, no doubt reflected in the present strong position of the four-cycle engine. In power per cylinder or per engine the average to-day with the two-cycle is higher than with the four-cycle engine. The reason for the preponderance of twin-screw ships is the desire to attain to total powers installed aboard comparable with the average steamship, and to achieve in propeller efficiency, a figure approaching that of slow-running steam engines. Of all the motor vessels over 80 per cent. are fitted with twin-screws.

It is interesting, further, to reflect that of the relatively few single screw vessels in construction, half are propelled by two-stroke cycle engines. The reasons for this may be firstly, that some of the largest powered units are of the two-stroke cycle type, and constructors who are willing to take the risks incumbent upon fitting the newer, less tried-out and less conservative type of engine would seem also to be willing now to take whatever risk, if any, there is in the policy of one marine Diesel engine per ship. The two-stroke cycle engines comprise, the opposed-piston types at present exclusively built in Britain, the supercharging port scavenging engine, originated in Switzerland and being built now chiefly in Switzerland and Italy, and the valve-scavenging engine which is only now retained by one French constructor.

In regard to the characteristics of the various countries, it is interesting to note that in Britain by far the greatest variety of engines are being constructed, these comprising standard four-cycle air-injection and four-cycle solid injection engines, two types of opposed-piston Diesels and supercharging two-cycle engines, and also single simple port-scavenging two-cycle engines. Sweden, Denmark and Holland are solidly in favour of the four-stroke cycle engine, and in America, very few two-cycle Diesel engines are in course of construction. In Switzerland and Italy are to be found the strongest protagonists of the two-cycle type.

In Britain not only is the greatest variety of type evidenced, but also the largest engines are being constructed, the most powerful, the four-cylinder opposed-piston two-stroke engine of 750 brake horse-power per cylinder. The cylinder diameters are 580 mm. and the stroke 1,160 mm., and the engine develops, at 70 revolutions in the four cylinders, a

total of 3,000 brake horse-power. The largest four-cycle engine being constructed in Britain, and also elsewhere, has cylinder diameters of 740 mm. by a stroke of 1,150 mm., and runs at 115 r.p.m., developing over 3,500 brake horse-power in eight cylinders. The two-cycle engines are of four and six cylinders—generally of four cylinders—and the four-cycle engines have six cylinders with a few exceptions where eight-cylinders are employed to give the desired high power.

The British policy of trying out all types of engine is certain to lead in the end to a very favourable position, and is a very bold policy to be commended in view of the lee-way which had to be made up and the lead unquestionably held by the earlier constructors of four-cycle engines. The unfortunate and unlikely event of failure with any of the newer types cannot now, in view of the varied and long experience already piled up to the good, be taken as evidence sufficient to condemn this prime mover in respect of its suitability for marine work.

ROADS IN WARFARE.

THE extraordinary state of disrepair which was the normal condition of European roads up to a century and half ago, fixed a low limit to the size of the armies it was possible to maintain. Many of Napoleon's feats would have been impossible had the means of communication at his disposal been no better than those with which Marlborough was perforce content. In fact, when his campaigns carried him into Poland, his calculations and plans were repeatedly upset by the previously unrealised importance of a "fifth element" in the shape of mud which caused divisions to arrive at their destinations hours too late. Railways greatly increased the possible size of the armies which could be fed and maintained, as was first demonstrated in the American War of secession; and it almost seemed at one time as if roads were becoming of secondary importance. The advent of the motor has, however, again emphasised the importance of good roads. Fortunately, this system of transport was relatively new when Germany launched on a (for the most part) unsuspecting world her long-planned dash for dominion and loot. A race which in the main pins its faith to organisation and erudition is, fortunately, at more disadvantage when confronted with novel conditions than others gifted with the greater insight and imagination needed for successful improvisation, and the fact that the allies in France were much more successful than the Germans in utilising for their armies the ordinary roads, was one dominant factor in bringing about the German defeat. This, it is now known, would have been finished as a veritable *débacle* had not the military chiefs decided to save their faces by insisting on the acceptance of any armistice, no matter how arduous the terms, rather than that they should themselves be saddled with the discredit of the wholesale capitulations to which the superior military abilities of the allies would have compelled them to submit, had the war continued but a few weeks longer.

A most interesting and detailed account of how this problem of road transport was solved has been written by Lieutenant-Colonel Lorieux, and is abstracted in a recent issue of the *Annales des Ponts et Chaussées*. France has long had a reputation for good roads, but these roads for the most part were never intended to serve for other than a very moderate traffic, and in general the metalled width does not exceed 3½ m. (11½ ft.). Hence as soon as the traffic became at all dense trouble ensued forthwith. The vehicles, in passing each other, were driven on to the unmetalled margins, cutting deep ruts in wet weather, and making the whole a mere mush. The metalled portion being no longer properly supported, began to spread, and, moreover, the wheels, as they came on or left the metalling, knocked pieces down into the slush at the sides. This further reduced the width of sound ground, thus aggravating the evil conditions. Fortunately, however, although narrow, the roads were numerous, and it was often possible to treat alternative routes as up and down lines. This method, though often the only alternative possible at the time, has its drawbacks, and hence the plan of widening the metalled way to 5·5 m. or 6 m. was adopted wherever possible. In all, some 9,000 km. of road were thus widened by an average of 2 m., the work done being thus equivalent to the construction of about 3,000 km. of new road.

At the outset of the war the organisation which normally maintained the roads was seriously upset by the withdrawal of men to the colours. This, however, did no particular harm, as it was found that an entirely different organisation was required for road repair and maintenance than sufficed in times of peace, and in the last year of the war over 78,000 men were at one time employed by the French on this service alone, in addition to those at work in the British and Belgian areas.

A more serious difficulty was the lack of adequate supplies of road metal and other paving materials. The pre-war practice had been to let contracts for road material in small lots to local undertakers, and for a period of five years only. The result was that contractors had no encouragement to equip their quarries with modern plant, but preferred merely to work the most easily-won material. Moreover, in the northern area of operations there is almost a complete absence of rock suitable for road metal, that available being a soft limestone or a bad sandstone, which would not last more than a few weeks under traffic. It was thus necessary to seek better stone at a distance.

New quarries were opened throughout France wherever suitable rock existed, and at one time there were 80 being worked to supply the needs of the Army. As, however, those nearest the scene of operations were developed, production from the more distant sources of supply was stopped. The question of transport was a difficult one. To supply the English area alone required the services of 15 to 20 trains per day during the last year of the war, whilst in 1917 the consumption in the French area rose to 23,000 tons per day. This traffic was at first not regarded with favour by the railway authorities, road metal being heavy and awkward to handle; but as experience proved the all-essential need of maintaining the supply, matters improved, the army chiefs insisting that priority should be accorded to the trains carrying road metal. One train could transport just enough road metal to renew the surface of ½ km. of road. Up at the front great use was made of farm carts, which could go where lorries could not pass. The maximum number in use at one time was 2,275, haulage being provided by 4,550 horses. More carts could have been usefully employed, but no more horses could be had. In addition, 1,700 lorries were employed in transporting the metal, no less than 423,800 tons being thus moved in July, 1918.

Road trouble first became severe in the course of the battles on the Yser, which brought to a stop the German rush to the channel ports. The weather was exceptionally rainy, and the roads became thoroughly waterlogged. The paved portion was only 3 m. to 3·5 m. (10 ft. to 11 ft.) wide, and was flanked by unmetalled side strips, which in the course of a few days of army traffic were reduced to quagmires in which the edges of the "pavé" disappeared. No road metal was available, and, moreover, the narrow gauge railways, of which most of the rolling-stock had fallen into German hands, could not have provided transport for it. The sole resource was to use brick, and after the ordinary stocks were exhausted walls were demolished to get additional supplies. The bricks were flung into the mud on each side of the road, and served to consolidate it. Old railway sleepers were also employed, either laid longitudinally as an abutment to the edges of the "pavé," or transversely across the unmetalled haunches as a foundation for the broken brick.

Some extraordinary difficulties arose in Champagne during the thaw of February, 1915. The surface strata here are chalk, and during the long frost preceding the thaw, the roads had been frozen through to the sub-soil. When the thaw occurred the damage done to the roadway was, it is stated, such as to be incredible to anyone who had not actually seen it. Warnings were sent to the army chiefs that transport must be restricted for several days, but the advice was disregarded, and as a consequence whole convoys, on entering the damaged roads, were, in a few instants, as completely stalled in the milky mud as if nailed in place. In subsequent years, emergency rations were issued to the troops for use during such periods of thaw.

On the German retirement which followed the Somme offensive in 1916, a specially heavy task awaited the road-builders. In the first place the French artillery had left the whole surface of the ground a chaos of intersecting shell holes, the destruction wrought being such that no trace could be found of a number of important roads, and it was only possible to locate them with the aid of the map. These roads, however, had to be made good, as it was impossible for railways to keep pace with the rapid advance. Work had to be carried on day and night, and as soon as the road was practicable it had to carry heavy military traffic of all descriptions. By means of throwing the metal on to the ground, under the very feet of the horses and under the wheels of the lorries the engineers ultimately succeeded in forming a serviceable road. With the advent of bad weather, however, came the worst plague of all; the mud of the Woëvre, which it is stated, acquired the worst reputation of any encountered during the war. To mitigate the evil, steps were taken to prevent mud being carried on to the roadway from the adjacent camps. The side ditches were enormously enlarged, and into these the mud was swept whenever sufficiently liquid to be dealt with. This condition was secured if necessary by artificial watering.

Roads of a temporary character had often to be constructed. For the most part these were made with planks 13 ft. long by 3 in. thick. These plank roads were found of great value during the pursuit of the enemy after his withdrawal on the Aisne and Oise and during his retreat in 1918 along the whole front from Nieuport to Verdun. On one occasion a plank road 1,800 m. long was constructed by 200 men in 36 hours. This lasted several weeks, whilst a more permanent roadway was being constructed alongside.

The mines used by the Germans to blow up the roads were generally situated at crossways and preferably at low spots into which water would drain. The craters measured as much as 35 m. (110 ft.) in diameter, and were from 6 m. to 8 m. (21 ft. to 28 ft.) deep. In addition, many delayed ignition mines were fixed under the causeway, which exploded several days, and in cases weeks, after being fixed. Others were discovered in time to be rendered innocuous. The mine craters caused much less delay and inconvenience to the pursuing armies than the Germans had anticipated. When in open country the ground was rapidly levelled on one side of the crater, and in dry weather this levelled portion would carry horse-drawn vehicles and light artillery for several hours, whilst more permanent repairs were in progress. Where no suitable materials were available at the spot, these further repairs were made with fascines or planking. The plan adopted was to lay six lines of plank spaced at 0·80 m. centres. A second layer of planking was then nailed on top of these longitudinals, and held in position by kerbing at each side formed of planks nailed or spiked to the second layer. Seven hundred planks, 4 m. (13 ft.) long, sufficed to construct 100 m. of roadway, and the work could be done by a gang of 60 men at the rate of 40 m. (130 ft.) per hour, and traffic could pass the moment the last nail was driven. These temporary deviation roads could be used without interfering in any way with the subsequent filling in of the crater.

The experiences of the war have demonstrated, M. Lorieux states, that the speed of the traffic is a more important factor in cutting up the roads than weight. It proved impossible, however, to control the speed, and the roads were only maintained in fair condition by constant patching, filling in holes as they formed with any material available, even turf being used for this purpose, where nothing better was obtainable.

Excellent results were obtained with tar painting, but the tar being required for other purposes, little was available, and its use in the French sector was confined to roads at the front, where it was absolutely necessary to prevent the passage of the traffic being disclosed to the enemy by clouds of

dust. In the British sector more tar was available, and it was freely used.

One point of importance emphasised by M. Lorient, is the necessity of confining the traffic to the metalled way. To this end stout piles were driven at frequent intervals along both edges. He states, further, that the crowning should not exceed one-fiftieth or, better, one-sixtieth of the width of the road. Otherwise the traffic seeks the centre of the roadway and ruts are quickly formed. The amount of road metal used by the French for road repairs and improvements amounted to 27,000,000 tons. The development of the motor traffic may be judged from the fact that the total employed by the French Army at the start was between 6,000 to 7,000 vehicles; and this increased to over 95,000 in the last year of the war. The British forces employed 45,000, plus 800 "caterpillar" tractors, and the American Army, 40,000. To this must be added the tanks, which, although capable of crossing almost any country, did not fail to make use of the roads when the conditions permitted.

WHAT IS A TRADE DISPUTE?

THAT Mr. Justice Astbury has the courage of his convictions regarding the proper interpretation of the Trade Disputes Act is clear from the judgment which he delivered last week in the case of White *versus* Riley and Wood, which arose out of an attempt by certain members of a trade union to compel a fellow employee to join it and leave his own union. The parties were all leather workers in the employment of the Leamore Currying Co. at Walsall. The plaintiff, White, was a member of the Workers' Union; the defendants, Riley and Wood, and the other employees in the shop were members of the Curriers' Society, Riley, as the oldest employee, being the spokesman of the shop, and Wood being a member of the executive committee and a district delegate. After certain unsuccesful efforts had been made to get the plaintiff to leave the Workers' Union and join the Curriers' Society, a shop meeting was held on November 28, 1919, and as a result a letter in the following terms was sent to the employers:—

> Sir,—We hereby give you notice that we shall cease work on Friday next unless E. White joins our Society or leaves your employment. Signed on behalf of the shop.—W. RILEY.

The employers apparently delayed taking action in the direction of dismissing the plaintiff, for some days, in the hope that the matter would be settled; but on December 5th, when the men's notice was about to expire, they were reluctantly compelled to dismiss the plaintiff, without notice, in order to avoid a strike. The plaintiff who had been earning 7*l.* 17*s.* per week, was out of employment from December 5, 1919 until January 12, 1920, when he was re-engaged at the works, with the shop's consent, on night work, on which he earned 6*l.* 2*s.* 9*d.* a week. He raised an action to have the defendants restrained from interfering with his employment, and his right to dispose of his labour as he willed, and alleged that the defendants had conspired by threats, intimidation and coercion to cause his employers to terminate his contract of employment, which had been done without notice as insisted upon by the defendants. The defendants denied that they had done anything unlawful, and relied on the Trade Disputes Act, 1906. This raised the question whether the defendants had acted in contemplation or furtherance of a trade dispute within the meaning of the Act, viz., a dispute "between employers and workmen, or between workmen and workmen, . . . connected with the employment or non-employment, or the terms of the employment, or with the conditions of labour, of any person." Now, in a similar case, Valentine *versus* Hyde, in 1919, Mr. Justice Astbury said that a trade dispute within the Act must be a dispute connected directly with employment or non-employment, and not a dispute about some entirely different subject-matter, the non-settlement of which may result in employment or non-employment, and he held that in cases of this kind the real dispute is as to whether the workman shall join the union, and the consequences with which he is threatened if he refuses, such as unemployment, form no part of the dispute. This view was criticised by Mr. Justice Peterson in the Electrical Trade Unions case, Hodges *versus* Webb, recently noticed in these columns, who said that if it was correct it would seem that the common difference between workmen and workmen on the subject of non-unionist labour is excluded from the operation of the Act, for the objection is not to their employment simpliciter but to their employment because or if they do not join the union. Mr. Justice Astbury has, however, adhered to the opinion expressed in Valentine *versus* Hyde, and has held that in the present case there was no trade dispute. "The only dispute," he said, "was on the question to which union the plaintiff should belong, and none of his fellow-workmen objected to his employment as such. All were perfectly willing to work with him, if he would comply with their demands." He therefore held that the defendants were not protected by the Trade Disputes Act, and he granted the injunction and found them liable to the plaintiff in £75 damages.

NOTES.

GRETNA AND WALTHAM ABBEY EXPLOSIVES FACTORIES.

A MAJORITY report signed by all but one of the committee appointed by the Ministry of Munitions to consider the future of the Gretna and Waltham Abbey explosives factories, has recommended that the former be retained and the latter abolished. The report points out that the Gretna factory is a modern one in every sense and is practically complete, and that it would be still more so if a few of the processes at Waltham were transferred at small cost to Gretna. This refers to the presses for rifle cordite, and the plant for Black Powder and Picric powder. Waltham Abbey factory, which is now old, and has a lay-out that is inconvenient and cannot be improved on the existing site, might be closed down altogether. It is suggested that the Gretna ether plant might be used for purposes outside the requirements of the factory itself, for the supply under Government control of cheap duty-free alcohol and ether, in order to give an incentive to industries requiring solvents. A small grant is proposed so that alterations may be made in order that experiments on a commercial scale may be tried in the manufacture of methyl-alcohol suitable for the dye industry. It is pointed out that work in this direction would not compete with existing trades, but would help existing industries. The minority report, which is signed only by Sir William Pearce, proposes to retain Waltham Abbey works as sufficient for the requirements of the country and to cut the whole loss at once on the Gretna factory.

THE IRISH COAL INDUSTRY.

It is not generally realised probably that there is a coal mining industry in Ireland of some latent possibilities. The industry it is true only turns out now about 90,000 tons per annum, while not far short of 4½ million tons are imported into the island. The Government committee which has recently had the subject under consideration is of the opinion that the output might be improved up to a possible 500,000 tons a year. This seems rather optimistic in view of the fact that the Irish deposits occur only in thin seams and that development is therefore expensive. The industry has since the middle of last century been affected by competition by imported coal, that is to say, as soon as transport facilities increased, serious competition developed. Now that the cost of transport is rather higher and English wages are higher, there would appear to be some prospect of developing the Irish industry. In fact the demand is said to be considerably greater at present than any possibility of supply. The coal is mostly good anthracite, and the proved reserves apparently amount to about 180,000,000 tons, with other probable reserves amounting to about 48,000,000 tons. For further development it appears to be necessary to provide better transport in some districts, and more housing accommodation. It is estimated that suitable houses could be put up for 500*l.* as most of the material would be available on the site. In order to develop the industry on sound lines, it is proposed that several changes shall be made in the Government control of this industry. A department of mines should be established within the Department of Agriculture and Technical Instruction, which should administer the coal mines regulations, &c. Adequate and competent geological staff should be provided. The Minister should have exploration powers on suitable terms of compensation, and should also be able to lease mines not being adequately worked or developed. It is also recommended that the State should assist the housing difficulty by subsidies for building and repairs in certain cases. Finally there should not for the present be any restriction of mine owner's profits. Certain advances of pay are conceded. The report proper records no opinion on the question of nationalisation, having taken no evidence in favour of it, but three of the members of the committee have thought fit to have added to it an addendum in which they give their ideas on the point. These are strongly in favour of State development, whether commercially practicable or not, and of national ownership.

POWER STATION PROGRESS.

Although every power station has its own points of interest and its own peculiar problems, none the less the modern station has become to some extent a standardised article, and the subject is not one which in general lends itself to any very original type of description. Numerous stations are dealt with from time to time in the technical press and in papers read before technical institutions, but the authors of these descriptions frequently appear to have difficulty in thinking of anything new to say. In view of this Mr. J. S. Watson is to be congratulated on his paper which was read before the North-East Coast Institution at Newcastle last Friday. The paper dealt to a large extent with Carville "B," the latest station of the Newcastle Supply Company, but the description was vivified by Mr. Watson leading up to it by a view of the various stations which historically preceded it in Newcastle. Mr. Watson divided his history into four chapters, or stages. The first covered the period from 1890 to 1899 when supply was restricted to lighting. The average size of generating units at this time was 200 kw., and the rate of growth of supply was 155 kw. a year. The second chapter covered 1899 to 1906, when the supply of current for power was developing. The annual rate of increase of supply was then 5057, kw., and the average size of units had increased to 2,453 kw. The third period, from 1906 to 1912 saw the development of the utilisation of waste power from coke ovens and blowing engines, and the annual rate of increase of supply was 11,942 kw. The waste-heat stations averaged 2,310 kw. capacity. The fourth stage, from 1912 to 1919, did not show any striking departure in method over earlier periods, but may be looked upon as the era of the big unit. During the period the average annual increase in supply was 9,714 kw., and the average size of new units installed was 11,330 kw. Some striking comparative figures were given for four of the stations concerned in the development. These were Pandon Dene, the earliest station, which was fitted with slow-speed, horizontal engines, and had a total capacity of 2,400 kw.; Neptune Bank, with slow-speed marine type engines and a total capacity of 5,200 kw.; Carville "A," the first turbine station which with extension reached a total capacity of 43,000 kw.; the size of unit averaging 5,400 kw.; and Carville "B," with 10,000 kw. units and a total capacity of 50,000 kw. Comparative figures for these stations are for steam consumption per kilowatt-hour:—Pandon Dene, 28·5 lb.; Neptune Bank, 18·8 lb.; Carville "A," 14·5 lb.; and Carville "B," 10 lb. The relative figures for kilowatt capacity per square foot of area occupied are 0·3 kw., 0·85 kw., 8·9 kw. and 15 kw., while the figures for kilowatt capacity per man engaged in operation are 141 kw., 145 kw., 409 kw. and 633 kw.

ECONOMY OF LOW-TEMPERATURE GAS GENERATORS.

The ordinary Mond gas generator is better adapted to the recovery of the ammonia than to the recovery of the tar, and the tar produced is poor in lubricating oils, because the tar liberated is partly decomposed by passing through layers of fuel at high temperature. That fact became very important in Germany during the war, and the

German Institute for Coal Research at Mülheim, on the Ruhr, devoted its main attention to the preparation of a low-temperature tar of higher lubricating value. While Franz Fischer and W. Gluud* worked out the problem of low-temperature carbonisation of coal and lignite with special regard to a high yield of "Urteer," *i.e.*, the tar in the original condition, Dr. Heckel, chemist to the Deutscher Kaiser Colliery at Bruckhausen, found means of extracting lubricating oils from this low-temperature tar. The economy of the gas producer was thus put on a different basis, and the present aspect of the problem was reviewed at length on behalf of the Verein deutscher Eisenhüttenleute by Dr. E. Roser in "Stahl und Eisen" of March 11, 18, and 25 last, on pages 249 to 358 and 387 to 395 of those issues. The report refers in particular also to the experimental runs conducted for three years in a gas-producer plant of the Works of Thyssen and Co., of Mülheim, but deals with the general economic considerations rather than with technical detail. The plant consists of 15 gas-producers, system Thyssen, provided with revolving grates to which air and steam are introduced from below; the tar vapours are, in their removal, drawn through cooler, and not through hotter, layers. Mention is also made of a Holzwarth gas-turbine for 700 kw., the spent steam of which is to be sent into the gas-generators to raise the ammonia recovery. Whether that gas-turbine will more effectually overcome the very serious difficulties that the efficient working of gas-turbines causes than did the turbine which Holzwarth described before the war, remains to be seen. But the economic questions discussed by Roser are interesting. In 1914 tar from gas generators fetched 40 marks per ton at the best, and 1 ton of coal yielded 50 kg. of tar, worth about 2 marks; it was more advantageous then to work for ammonium sulphate than to push the tar yield. The new low-temperature tar proved much more valuable; it contained 40 per cent. of light oils (against 17·5 per cent. in the old tar); 17 (6) per cent. of lubricating oils; no naphthenes; anthracene, &c. (11 per cent); 2 (0) per cent of paraffin and fats), and 40 (39) per cent. of pitch. It was, moreover, found that the vauable properties of the new tar were practically retained when the coal was mixed with half its weight of lignite; lignite is one of the most important mineral resources of Germany. By itself, the lignite yielded 25 kg. and more of tar, free of water; in the mixtures of coal and lignite the tar yield rose to 75 kg. per ton of fuel, and the value of the tar (up to 16 marks per ton in pure coal) to more than 6 marks. Roser appears to disregard, in his comparative estimates, the extraordinary rise in prices that Germany has experienced during and after the war, though he refers to changes in official dues. He deals, moreover, with specifically German conditions. But one may probably accept his conclusion that with high coal prices, low-temperature carbonisation combined with recovery both of tar and ammonia, is economically advisable, when the gas is to be utilised both for power and for heating purposes.

THE IRON AND STEEL INSTITUTE.

THE fifty-first annual general meeting of the Iron and Steel Institute was held yesterday and is being continued to-day at the hall of the Institution of Civil Engineers, Westminster, Mr. Eugene Schneider, the retiring president, occupying the chair at the beginning of the proceedings.

THE REPORT OF THE COUNCIL.

This opened by stating that at their meeting on November 20, 1919, the council nominated Dr. J. E. Stead, F.R.S., vice-president, to succeed M. Schneider as president of the Institute. The notice of Dr. Stead's acceptance of the office was received with great gratification by the members.

During the past year 153 new members and 14 associates were elected, and the total membership on December 31 was: Patron, 1; honorary members, 4; life members, 75; ordinary members, 2,040; associates, 61; total, 2,181.

The council took the opportunity of the meeting to offer their congratulations to several members who had honours conferred upon them. Mr. Schneider had been awarded the Cross of an Officer of the Legion of Honour; also on the occasion of his recent mission to the United States he was elected an honorary member of the American Iron and Steel Institute. He received the honorary degrees of Doctor of Science of the Universities of Pittsburgh and Cleveland and of Doctor of Engineering of the Stevens Institute of Technology, and had conferred upon him the Freedom of the City of Pittsburgh. He also received the gold medal of the American Institute of Mining and Metallurgical Engineers. Colonel John Roper Wright had been created a baronet. Mr. Christopher T. Needham had the honour of knighthood conferred upon him. Mr. H. Dennis Bayley and Mr. T. Harris Spencer had been created Knights Commanders of the Order of the British Empire. Major W. Burnyeat had been awarded the Distinguished Service Order. General R. K. Bagnall-Wild had received the Order of the Cross of St. Michael and St. George. Mr. C. J. MacGuckin, Dr. A. McWilliam, and Mr. R. P. Sloan had conferred upon them the Commandership of the Order of the British Empire, and the following had been created Officers of that Order: Captain C. A. Ablett, Mr. H. Bates, Lieutenant-Colonel J. G. Needham, D.S.O., Captain P. W. Smith, and Mr. Frank Somers. The Freedom of the Blacksmiths' Company had been conferred on Mr. Schneider, and on Sir William Beardmore, Bart.

The accounts of the Institute showed that the total receipts during the year under review, excluding the income derived from the Carnegie Research Fund, were 5,979*l.* The expenditure for the same year reached 7,088*l.*, thus revealing a deficit on the accounts for the year 1919 of 1,109*l.* Notwithstanding that the income had exceeded that of any previous year in the history of the Institute, it had unfortunately been insufficient to meet the increased expenditure, due principally to the greatly enhanced cost of printing and publishing the Journal.

In these circumstances it had been found necessary partly to meet the deficit by realising some of the invested funds of the Institute, and 1,000*l.* of 5 per cent. War Stock (1929–1947) was sold for this purpose, the balance being met by a temporary advance from the accumulated income of the Carnegie Scholarship Fund. War Loan Stock to the amount of 1,000*l.* had since been transferred from the invested funds of the Institute in part discharge of this advance. The whole situation had received the careful consideration of the council, who appointed Mr. Illtyd Williams (hon. treasurer), Mr. Steer, Mr. Rylands and Mr. Harbord, a Finance Committee to deal with the matter. Acting on the recommendations of this committee, the council had now under consideration the question of raising the annual subscription. As, however, no such action can become operative without amending the bye-laws, and as no resolution thereto can take effect before 1922, the council had recourse to an appeal to the members voluntarily to increase the amount of their subscriptions in the current year, an expedient which it was hoped would, in the interim, enable the Institute to meet the deficiency which it was anticipated would again occur in the forthcoming twelvemonth.

The income of the Carnegie Research Scholarship Fund during 1919 was 1,018*l.*, and the expenditure was 525*l.* The surplus income over expenditure was therefore 493*l.*

SPECIAL FUND.

In April, 1919, the council invited the iron and steel makers of the United Kingdom to subscribe to a Special Fund, the interest on which should be applied to the extension of the work of the Institute, and of the various technical committees formed to promote metallurgical practice, and to assist by donations and annual subscriptions educational schemes for scientific, technical and industrial training. In response to this appeal a sum of 11,036*l.* was subscribed, of which 7,616*l.* was actually received before the end of the year, with promises of a further 3,420*l.* during the next two years.

COMMITTEE WORK.

During the year a number of meetings had been held by the Technical Committees appointed in 1917. The Sub-Committee on the Production of Sound Steel delegated to Mr. F. W. Harbord, C.B.E., the collection of details of the various processes extant for the manufacture of sound ingots, and an interim report had been received from Mr. Harbord, which will be duly considered by the committee. The Sub-Committee on Standard Steels had held three meetings, two in London and one in Sheffield. Standard steel ingots had now been selected by five of the district authorities, as follows: Middlesbrough (carbon, 0·1 per cent.); North Midlands (carbon, 0·66 per cent.); Glasgow (sulphur, 0·03 per cent.); South Wales (sulphur, 0·07 per cent.); Birmingham (phosphorus, 0·076 per cent. to 0·080 per cent.). The North Midland (Sheffield) authority's selected ingot had been sent to Teddington for ultimate check analyses and preparation of standards.

THE NEW PRESIDENT.

Mr. Schneider, the retiring President, then inducted into the chair the new President, Dr. Stead, and said that Dr. Stead's election showed the co-operation which existed in the Institute between the metallurgical industry and science. Thanks to Dr. Stead's work the history of a metal could be read at the various phases of its manufacture. His own (Mr. Schneider's) election was a compliment also to France. It showed how bonds of fellowship had been formed during the war between the two countries; those bonds would be followed up in peace and the Institute would form one of the permanent links joining the allies together.

Sir Robert Hadfield and Mr. Arthur Cooper expressed the thanks of the Institute to Mr. Schneider for his period of chairmanship.

THE BESSEMER GOLD MEDALLIST.

The first duty performed by the new President was to present the Bessemer gold medal for 1920 to Mr. Harry Brearley. In doing so, Dr. Stead traced Mr. Brearley's career; and the latter, in responding, paid tribute to the assistance he had always received from his brother, Mr. A. W. Brearley, and to the indebtedness he owed to every member of the staffs with whom he had been connected throughout his life.

FREEDOM OF THE BLACKSMITHS' COMPANY.

Dr. Stead then announced that the freedom of the Blacksmiths' Company had been conferred on Mr. W. H. Cathcart, Renfrew, the author of the book entitled "Value of Science in the Smithy and Forge."

PRESIDENTIAL ADDRESS.

Dr. Stead next proceeded to deliver his presidential address.

This was a condensed review of the progress made during the past fifty years in the ferrous industries, period during which Dr. Stead had been connected with metallurgy. The address was divided into sections and, commencing with the blast furnace, Dr. Stead pointed out the conditions which ruled in 1870 and the developments which had taken place down to the present day, from the standpoints of dimensions, the proportioning of the various parts of the furnace itself, its accessory apparatus, the actual working, special stress being laid upon the utilisation of the blast-furnace gas; the recovery of the heat in the blast-furnace slag was also referred to. Dr. Stead said it was now universally admitted that the coke ovens should be close to the blast furnaces, and this was still more necessary if steelworks were in association with the blast furnaces, when all the excess of coke-oven gas could be used in the steel works.

After reviewing the manufacture of iron in the puddling furnace, Dr. Stead dealt with the early attempts to make steel from phosphoretic irons and gave a history of the basic Bessemer process, a process which put an end to the early attempts in question. He traced the development of the basic Bessemer process from its inception, and indicated the progress which gradually took place both in regard to the use of suitable materials—for the lining of the converters and for carburising the heat notably—and in the carrying out of the process itself, until this was made a complete success. In the matter of Bessemer steel proper, he pointed out

* Compare Coal Research in Germany, ENGINEERING, August 15, 1919, page 217.

that in a little more than fifty years this acid steel which had practically superseded wrought iron for rails and other material was now superseded by open-hearth steel.

His remarks on the open-hearth process covered manufacture from the first operations; one of the great metallurgical advances during the period under review was the use of liquid metal from the blast furnace and the introduction of the mixer. The address dealt with the various methods of working the open-hearth process, the dates when these methods were introduced, typical charges and analyses, the names of metallurgists and works, and outputs being given.

Soon after 1914 a large number of electric melting furnaces—mainly of the Héroult type—were erected in this country to deal with the enormous mass of shell borings produced. The electric furnaces had been used largely to replace crucible melting and had come to stay. Immense quantities of special alloy steels were made by their aid and, since the war, in one works at least, the greater part of crucible steel had been replaced by electric steel. At the end of 1918, the number of electric furnaces of all types in England was about 140, having a production of about 150,000 tons a year, and a transformer capacity of nearly 100,000 k.v.a. The possible production to-day, if all furnaces were worked to their full capacity, was about 300,000 tons per year.

The important subject of "sound steel ingots" formed a special section in the address, and in this Dr. Stead reviewed the work carried out by various metallurgists, on various lines, to obtain sound steel, *i.e.*, thermal methods, and those in which hydraulic pressure is applied to the ingot during the process of its solidification.

After dealing with the Wellman furnace charging machine—one of the most important developments in connection with the open-hearth process—with the utilisation of basic slag, and the use of powdered coal in steel manufacture, Dr. Stead pointed out the position which science now held in practical metallurgy. He showed the progress which had been made in analytical chemistry and referred in detail to the birth and the development of metallography, a science in which the names of Sorby and Arnold, Osmond and Le Chatelier, Howe and Sauveur, stood out prominently as the pioneers, a science in which, we may be allowed to add, Dr. Stead has acquired a world-wide reputation.

The address closed with reference to the encouragement of research which had been afforded by members of the Institute, namely Sir Henry Bessemer, Andrew Carnegie and Sir Robert Hadfield. The Institute, moreover, had from time to time subscribed considerable sums for the advance of education and research outside its own body, but had not donated anything towards the encouragement of research by its own members, a condition of things which it was hoped would be remedied in the near future. Coupled with this question of research was that of technical education, and Dr. Stead stated the example of his lectures on steel to workers in his district; the scheme for acquiring knowledge started by the workers of Messrs. Brown, Bayley's Steel Works, Sheffield, and similar movements in connection with other establishments, were also mentioned. The work of the Institute in this respect was also alluded to, and suggestions thrown out for increasing the usefulness of central London technical institutes, one being the passing on to local institutes of papers for their further discussion in the provinces. The address formed a most complete and interesting compendium on ferrous metallurgy; it will repay careful reading and will be found most useful for reference purposes.

A vote of thanks to the President for his address was moved by Professor Henry Lewis, who expressed satisfaction at the emphasis which had been laid by Dr. Stead on the advantage of scientific training throughout. The address as a whole afforded an example of the care which the president gave to all matters.

The first papers on the programme were then read and discussed. We shall deal with these and with the continuation of the proceedings in our next issue.

(To be continued.)

LITERATURE.

Electricity in the Service of Man. A Popular and Practical Treatise on the Applications of Electricity to Modern Life. By R. MULLINEUX WALMSLEY, D.Sc.(Lond.), F.R.S.E., Principal of the Electrical Engineering Department of the Northampton Polytechnic Institute, London. Vol. II. *Technology of Electricity, Section II.* London: Cassell and Co., Limited. [Price 10*s.* 6*d.* net.]

THIS volume is a portion of a large and comprehensive work of which substantial portions have already appeared. The uses of electricity are so many and varied, that to describe them all with any approach to thoroughness is to undertake a task of no ordinary difficulty. Few would care to travel over the whole field of technical operations involved in the many applications of steam, and in electricity the range of operations is even wider. Considering that the publication of the successive volumes has undoubtedly been very seriously delayed by the war, it appears to us that it would have been desirable to give—even at the risk of repeating information already published—some clear indication of the scope of the work and of the plan on which it is organised; but no word of preface or explanation is vouchsafed. It is, therefore, equally impossible for the reader into whose hands the book now comes for the first time to decide whether the plan was judiciously conceived, or successfully carried out.

The work certainly suffers one inconvenience, the publication—probably owing to no fault of the author or publisher—has certainly been long drawn out. The first instalment was issued early in 1911, the second contribution followed in 1913, and the third is now before the public. We are promised 3,000 illustrations in all, apparently only one-half has now appeared, from which it may be concluded that the end of the complete work is yet far distant. From internal evidence it is to be inferred, that the theory of many of the instruments appeared in the earlier volumes, and the separation of the theory from the method of application is, to say the least, unfortunate. For instance, this instalment opens with a chapter on alternate-current motors and a sense of disappointment will probably be experienced on reading in the first sentence, that as the principles underlying the construction and working of these machines, both monophase and polyphase, have already been presented in the first volume, only the application will be considered now. The same sentence further indicates an arrangement which is not without objection, for the purpose of the present chapter is declared to be the description of several representative machines that illustrate those principles. This gives the opportunity for reproducing the diagrams of apparatus designed by many eminent firms for effecting definite purposes, but at the same time it gives the book more or less the appearance of a trade catalogue. This feature, which grows increasingly prominent in subsequent chapters, is common enough in semi-popular works, where it is not unusual to describe "systems" rather than discuss principles, but in this treatise the practice is carried to excess.

We notice, too, a tendency to disparage the use of mathematical investigation. In one passage the grounds for this mistrust are assigned to the inadequate methods of approximation, frequently adopted by mathematicians, by which the influence of small factors is neglected, "and pretty geometrical demonstrations are developed, some of which may be regarded as mere intellectual exercises." There are, however, it is intimated, other demonstrations, which are of real practical value, which enable "the designer to predetermine the performance of a motor not yet constructed."

Dr. Walmsley is at his best when theoretical considerations are in abeyance, and he is explaining the purpose for which a machine is designed. In the chapter on dynamo and motor testing, for example, where methods have become stereotyped by experience, the arrangement and description leave little to be desired, though one may be inclined to dissent from the statement that the objects of test instituted by the manufacturer and the user of the machine are not identical.

The important subject of "Transformers" is treated under the four divisions of "Static transformers," "Kinetic transformers," "Secondary Batteries" and "Rectifiers." The technology is sufficiently full, the development is easily followed, the illustrations are informing, and most important of all, references to earlier volumes are not so irritating.

In the section on the transmission and distribution of electrical energy a new subject is opened, and again the technical details are well explained. Whether the description refers to the supports carrying an overhead wire, or to the troughs in which an underground cable is solid laid, there is not much room for mathematical investigation. When the voltages rise, however, to 150,000 volts, problems have to be considered that are rather hinted at, than solved. There are limiting factors not yet reached—for skill and daring rise with the emergencies to be met—that determine the possible voltage for overhead transmission about which more information might have been usefully provided; but the chapters on this subject, which include the provision of substations and of protective gear for electric circuits are exceedingly interesting as they demonstrate the possibility of new sources of energy and the flexibility of electricity, the ingenuity exhibited in dealing with and controlling enormous forces, and the judicious combination of means to produce the most economical result. Those who possess the earlier instalments of Dr. Walmsley's work will heartily welcome the additional volume now under notice, and they will no doubt be anxious for the appearance of the further instalments required for its completion. As a whole, it will undoubtedly form a very useful book of reference.

BOOKS RECEIVED.

The Railway Year Book for 1920. London: The Railway Publishing Company, Limited. [Price 5*s.* net.]

Notes on Irrigation, Roads and Buildings and on the Water Supply of Towns. By WILLIAM LUMSDEN STRANGE, M.Inst.C.E. London: George Routledge and Sons, Limited. [Price 45*s.* net.]

Industrial Administration. A Series of Lectures delivered at the College of Technology, Manchester. London: Longmans, Green and Co. [Price 7*s.* 6*d.* net.]

Electric Welding and Welding Appliances. By HERBERT CARPMAEL, A.M.Inst.C.E., A.M.I.E.E. London: Constable and Co., Limited. [Price 18*s.* net.]

Forests, Woods and Trees in Relation to Hygiene. By AUGUSTINE HENRY, M.A., F.L.S., M.R.I.A. London: Constable and Co. [Price 18*s.* net.]

Willing's Press Guide and Advertisers' Directory and Handbook, 1920. London: James Willing, Limited. [Price 2*s.*]

Water Powers of British Columbia, including a Review of Water Power Legislation relating thereto and a discussion of Various Matters respecting the Utilisation and Conservation of Inland Waters. By ARTHUR WHITE, Consulting Engineer, Commission of Conservation, assisted by CHARLES J. VICK. Ottawa: Commission of Conservation, Canada.

RESEARCH AND EDUCATION IN AERONAUTICS.—From a statement issued by the Secretary of the Air Ministry, issued on Tuesday last, we learn that the recommendations of a committee under the chairmanship of Sir Richard Glazebrook, appointed by the late Secretary of State for Air, Lord Weir, to replace the Advisory Committee for Aeronautics by an Aeronautical Research Committee, and also to establish a Department of Aeronautics at the Imperial College of Science, have been adopted. The principal terms of reference of the Aeronautical Research Committee are to advise on scientific and technical problems relating to the construction and navigation of aircraft; to undertake, or supervise, experimental or research work; to take over complete responsibility for the Air Inventions Committee and for the Accidents Committee; to promote education in aeronautics by co-operation with the governors of the Imperial College; and to assist the aeronautical industry of the country by scientific advice and research. The members of the committee appointed are Professor Sir R. Glazebrook (chairman), Wing-Commander W. D. Beatty, Lieutenant-Colonel E. Gold, Air Commodore H. R. M. Brooke-Popham, Wing-Commander T. R. Cave-Brown-Cave, Professor L. Bairstow, Professor Sir J. E. Petavel, Mr. Alex. Ogilvie, Mr. H. White Smith and Mr. J. D. Siddeley, with the following scientific representatives: Professor H. Lamb, Professor W. E. Dalby, Professor B. M. Jones, Mr. G. I. Taylor, and Mr. H. T. Tizard; Mr. J. L. Nayler will act as secretary and Mr. J. G. Gibson as assistant secretary. Sub-committees will be appointed to deal with accidents, air inventions, aerodynamics, engines, meteorology and navigation and other matters, as required. The organisation and staffing of the Department of Aeronautics at the Imperial College are proceeding under the direction of Sir Richard Glazebrook, as Zaharoff Professor of Aviation, and the recommendation of a grant from public funds towards the cost of the department has been approved.

NOTES ON NEW BOOKS.

A GOOD number of the troubles experienced by the everyday user of machinery are due more to neglect, or perhaps one should say to uninstructed care, rather than to defects of design, or material. It is difficult for a really skilled man always to realise what the ordinary user is capable of doing, or failing to do, to machines under his care, and statistical records of the effect of such usage, when obtainable, are of considerable value. From this point of view we would commend a little booklet recently published by the National Boiler and General Insurance Company, of Manchester, at the price of 1*s*. The booklet is entitled "*Notes on Gas and Oil Engine Accidents*," and is intended for users of such engines. It describes the more usual forms of such accidents and their causes, and gives information which should enable them frequently to be avoided. The information in the book is based on the experience of the company, and should be of interest to engineers even though many of the methods proposed naturally concern the A B C of their business. There are some points, however, which will be new to many engineers, as, for instance, the bursting of the plugs of stopcocks owing to the freezing of the water trapped inside them. The remedy proposed is the drilling of a hole in one side so that the plugs drain themselves.

There are various ways of compiling technical pocket and reference books, and it is not possible to say that any one of them is best. In the limits the methods approach either a collection of data and definitions arranged alphabetically, or fully indexed, or, on the other hand, a collection of short treatises dealing each with some branch of the subject covered by the work. The first type is the more immediately useful for reference, but the information supplied is to some extent necessarily brief and disconnected. The second type, given the time and patience to employ it properly, should in the end supply fuller and more usable information. This second type, to be as useful as it can be made, should contain a very adequate index, and we are inclined to criticise "*Whittaker's Electrical Engineers Pocket Book*" on this score. A new edition of this work, edited by Mr. R. E. Neale, has just been published by Sir Isaac Pitman and Sons, at 10*s*. 6*d*. net, and shortly after receiving a copy we happened to want to check the definition of "lumen." The index proved to be no help, and it was necessary to glance through a fair part of the section on "Light and Photometry" to find what we required. The information was given very clearly and adequately, but the incident illustrates what seems a defect in the publication. The various sections appear very complete and informative, and on such subjects as switch gear and electro-chemistry much matter appears to have been brought together which cannot be found collected elsewhere. Each section forms a brief treatise and is logically arranged so that it may be read through systematically. A perusal of the whole book would be valuable not only to the student, but to the practical engineer in giving an adequate review of various electrical fields with which we may not normally be concerned.

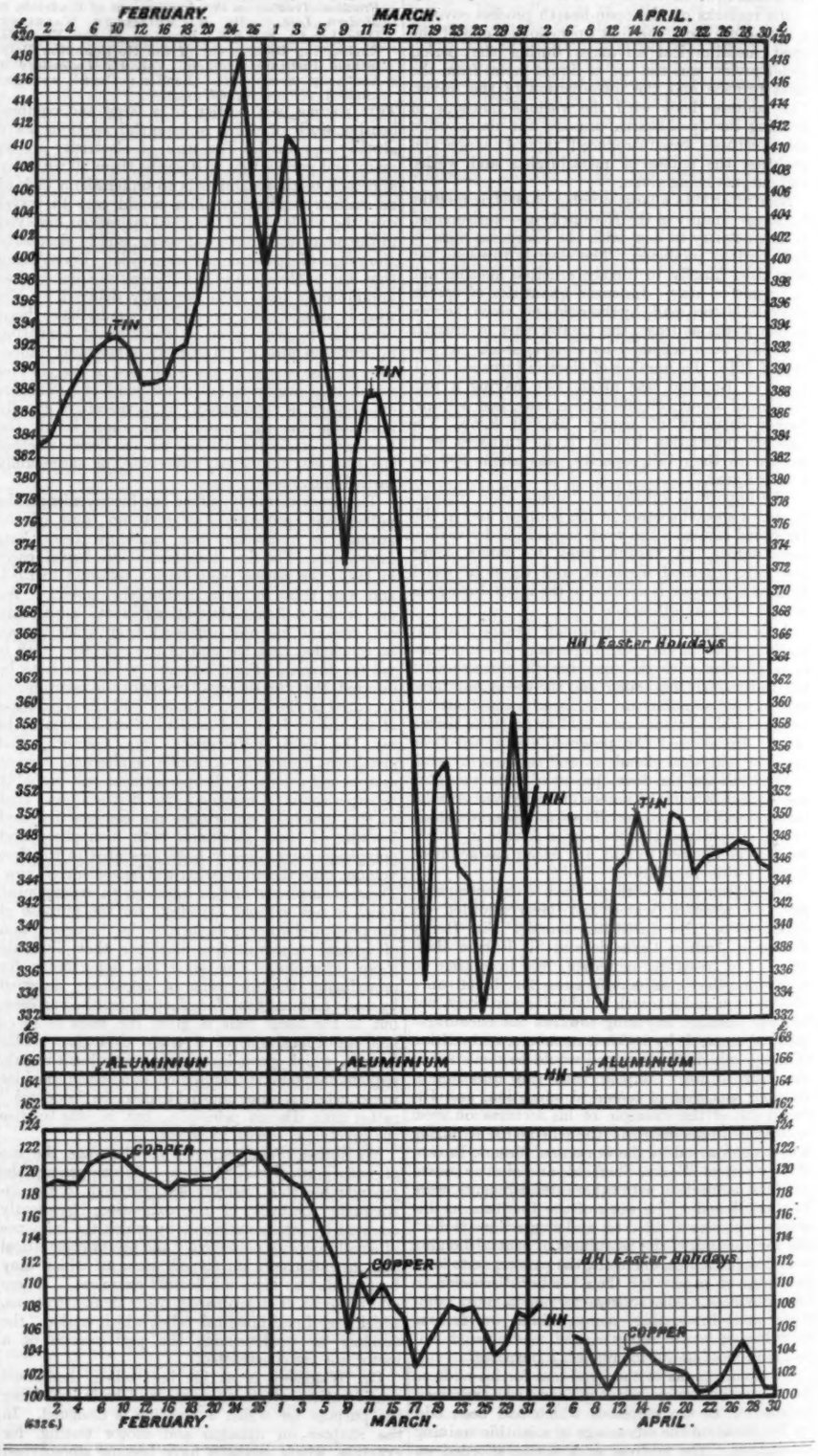
The subject of coal conservation is one on which we have had a good deal of advice lately. It is admittedly of immense importance to the nation, as it is naturally desirable to defer as long as possible the day when we shall become dependent upon foreign supplies. The Coal Commission has given us its views on the subject, which, however, have been seriously called in question. Sir Dugald Clerk and Mr. Brownlie have discussed the point, and now we have Mr. W. H. Casmey bringing forward his views in a small book entitled "*Coal Economy*" (Charles Griffin, London, 2*s*. net). Mr. Casmey's estimate is for a possible economy of something like 50,000,000 tons. He suggests that most Lancashire boilers are designed with too large a grate area, and would be more economical if this feature were reduced. In many cases economy has followed on conversion. Eighteen million tons of coal is the author's estimate for possible economy in this direction. To this he adds from 7,000,000 tons to 9,000,000 tons which could, in his opinion, be saved by proper attention to draught conditions, and economy in fuel salved from ashes another 10,000,000 tons. Finally, if a few simple rules be attended to with regard to domestic fires the author points out that a considerable saving is possible from this source. The author recognises the fact that individual plants are unavoidable in many instances and could not be replaced by power production in bulk. His book is intended to apply to the improvement of existing plants and their control, and many of his points are worth attention.

THE MOTOR-SHIP FULLAGAR.—We are informed that the motor ship Fullagar, which was built by Messrs. Cammell Laird, Birkenhead, for the Anchor-Brocklebank Line, and fitted with the new "Cammellaird-Fullagar" oil engine, which was illustrated and described on page 144 *ante*, ran highly satisfactory trials last week off the Mersey.

THE NOTTINGHAM SOCIETY OF ENGINEERS.—On Tuesday, April 27, members of the Nottingham Society of Engineers, to the number of about 80, visited the works of Messrs. Herbert Morris, Limited, Loughborough, where they were shown various types and sizes of cranes, runways, telphers, hoists, pulley blocks, &c., in finished state, in course of manufacture and at work. The visitors very favourably commented upon the organisation of the company for specialising on repetition lines, together with the arrangements made for the welfare of the employees.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(*Specially Compiled from Official Reports of London Metal Markets.*)



DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

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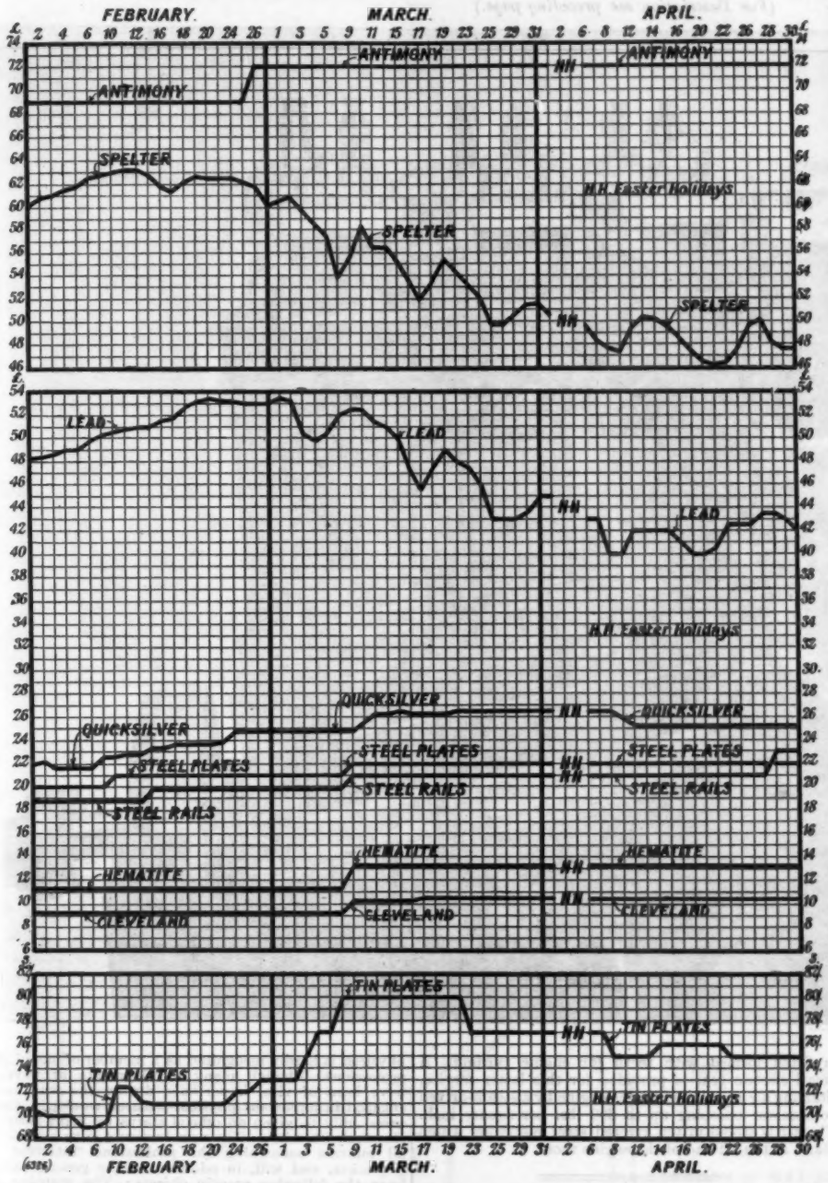


NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig iron. The prices given, in the case of steel plates, are for ship, bridge, and tank qualities, and those for steel rails are for heavy sections. The pig iron prices are for East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

CONVERSION OF GUNBOATS INTO CARGO STEAMERS.—Messrs. J. Samuel White and Co., Limited, East Cowes, I.W., inform us that they are now converting eight "Kil" Class gunboats into cargo steamers. The majority of these vessels were built by Smiths' Dock Company, at Middlesbrough, and their dimensions are, generally, as follows: Length between perpendiculars, 170 ft.; beam, 20 ft. 10 in.; and depth, moulded, 16 ft. 6 in. The conversion is being carried out in compliance with British Corporation Rules, Class B.S.* and the work includes the straightening of the stem and the building of a forecastle. Each of the boats is equipped with two boilers, of which the forward one has to be removed and the space adapted to a cargo hold. The existing triple-expansion engine will remain in its original position, and will give a speed of about 10 knots. The conversion allows for a dead-weight capacity, including bunkers, of 650 tons, of which the coal bunker capacity is to be 80 tons. The forward cargo hold is to have a capacity of 23,000 cub. ft., with a cargo hatch 38 ft. by 19 ft., and the after cargo hold 5,900 cub. ft., with a cargo hatch of 22 ft. by 11 ft. Two steel masts are to be fitted to each boat, and a wood derrick having a 3-ton lift is to be placed at each mast. A cargo winch 6 in. by 10 in., will be fitted at each hatch. Accommodation has to be provided for 19 officers and men in each ship. The crew will be berthed under the forecastle, and the side plating amidships will be extended to enclose the bridge space, where accommodation will be provided for the officers on the main deck, while the chart and wheel-house will be on the bridge deck. The time occupied in the work of converting each ship is expected to average about two months.

OIL ENGINES OF THE MOTOR SHIP "NARRAGANSETT."

THE illustration on page 624 shows one of the main propelling engines of the motor ship Narragansett which has been constructed and engined by Messrs. Vickers, Limited, of Barrow-in-Furness. The boat has been built for the Anglo-American Oil Company and is to be followed by a sister ship, the Seminole. The Narragansett was launched in November last and will undergo her sea trials this month. She is a boat of 14,000 tons displacement at her mean draft of 26 ft. Her deadweight capacity is 10,050 tons, her length between perpendiculars 425 ft., moulded breadth 56 ft. 8 in., and moulded depth to upper deck 33 ft. She is designed to carry a normal cargo of 9,420 tons of oil and 510 tons of oil fuel. The boat is built on the Isherwood system of longitudinal framing and the main cargo space consists of ten tanks divided into pairs by a longitudinal centre-line bulkhead. There are two sets of cargo pumps each capable of pumping 200 tons of oil an hour. Oil is drawn from the cargo tanks through two lines of piping 10 in. in diameter and delivered into a deck line. Any tank can be filled, or emptied, independently of the remainder, and branches are fitted so that the oil may be delivered over either side. Valves for automatically maintaining atmospheric pressure in the oil tanks are fitted on the tank hatches.

The main engines consist of two sets of Vickers solid-injection type oil engines, but the auxiliaries are in the main steam driven. This arrangement has been come to owing to the necessity for providing steam in considerable quantity for heating and tank steaming purposes. The oil pumps, already mentioned, are steam driven as are the compressor, ballast, fire and bilge, fresh-water and other pumps. One of the two electric light and power engines is also steam driven, the other being a Vickers-Petter low-compression oil engine. There are two boilers, one cylindrical and the other vertical. They are fitted for oil-burning. The main feature of interest is, of course, the main engines, one of which is shown in our figure. In the Vickers type of oil engine instead of using an air compressor in conjunction with a fuel pump for spraying the fuel into the cylinder, the injection is effected by the fuel pump alone. This difference is in the direction of simplicity. The engines are each of six cylinders, 24½ in. in diameter and 39 in. stroke. The two sets are designed to develop in conjunction 2,500 brake horse-power at 118 r.p.m. The first engine was tested by daily running over four weeks in the shops, but owing to the moulders' strike delaying the dynamometer gear, it was necessary to confine full-power trials to four cylinders at a time. The second engine was put on official trial as soon as it was completed owing to the urgency of delivery. She did a full day's run with all cylinders on overload and developed 1,350 brake horse-power at normal revolutions, and with a clean exhaust. The fuel consumption was below ·44 lbs. per brake horse-power per hour. The maximum cylinder pressure during this run was maintained below 500 lbs. per square inch, although in preliminary runs injection was advanced to give over 600 lbs. at normal load to test the engine.

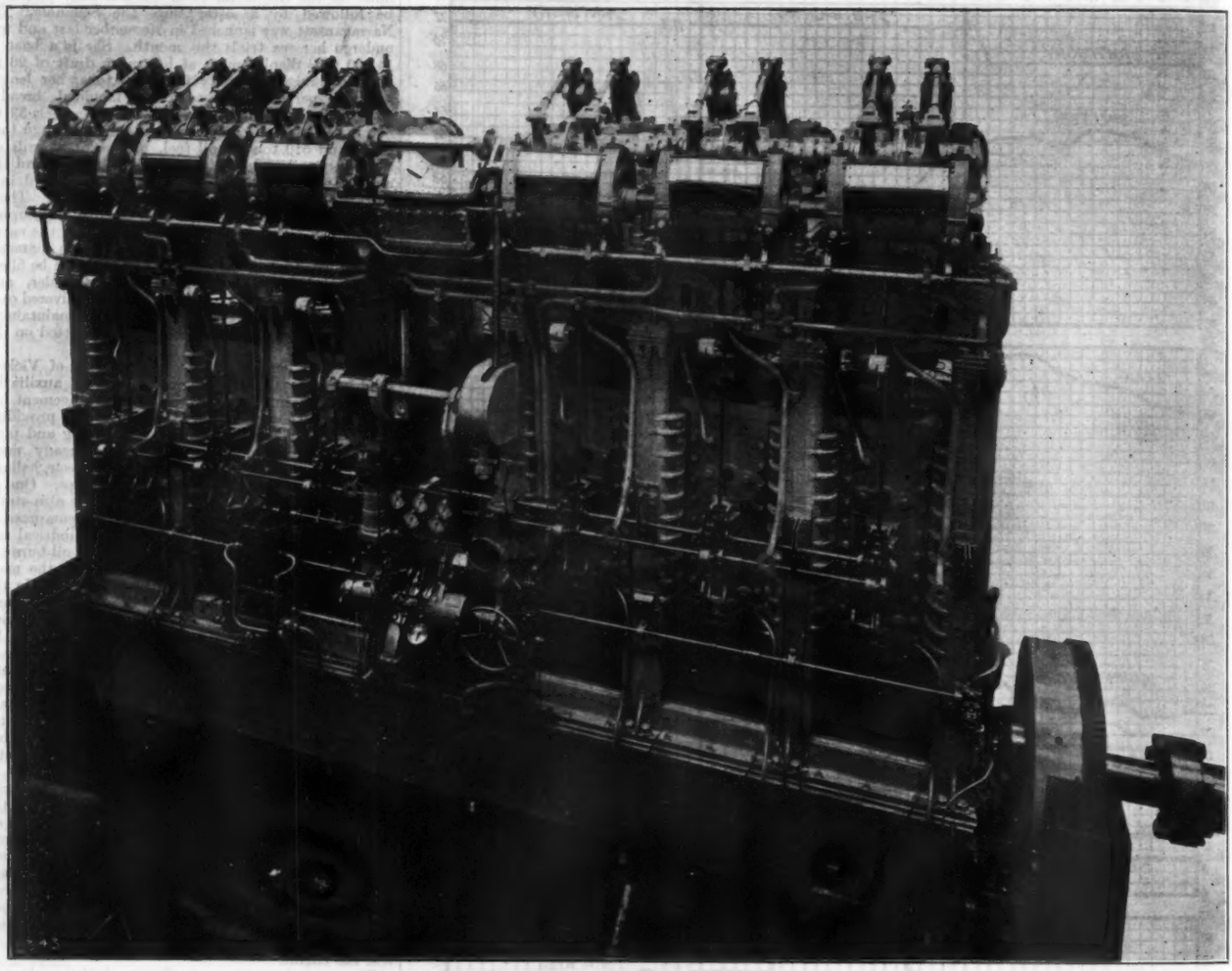
The general appearance of one of the engines is well shown in our figure. The main construction consists of hollow cast-iron columns straddling the main bearing and attached at top and bottom to the cylinders and bedplate. The cylinders are cast separately and bolted together at the bottom to form a continuous girder. The columns support the single slipper guides and impart rigidity to the engine, but do not carry the main impulse loads which are taken by steel tie rods which run through the columns. The bed-plate is in two pieces and is filled in solid to prevent leakage of oil into the bilge. The cylinders are of cast-iron with liners which are supported at the top, but are free to expand through a gland at the lower end. Each cylinder is fitted with one inlet and one exhaust valve. The fuel injection valve is between the two and the air-starting and safety valve is at the back. The crank-pit is separated from the cylinders by a diaphragm plate through which the piston rods pass through elementary glands which prevent oil leakage. This diaphragm is arranged as a tray with a drain, which collects any burnt lubricating oil dropping from the pistons, or water from the piston cooling glands, and thus prevents the lubricating oil from becoming contaminated. The lubricating of all parts within the crank case is by pump, the oil passing from the main bearings to the crankheads and thence to the top ends. The pistons are lubricated by sight-feed pumps.

Reversing is carried out by sliding the cam-shaft which is fitted with ahead and astern running cams. During reversal the induction and exhaust cam rollers are lifted clear of the cams by oscillation of the fulcrum shaft upon which the cam levers are eccentrically mounted. The power is supplied by an air servomotor

HEAVY OIL ENGINES OF THE MOTOR SHIP "NARRAGANSETT."

CONSTRUCTED BY MESSRS. VICKERS LIMITED, ENGINEERS, BARROW-IN-FURNESS.

(*For Description see preceding page.*)



with a dashpot cylinder. When the reversing lever has made its full travel in the direction indicated by the reversing lever the engine can be started, the starting wheel, until this position is reached, being locked in the "stop" position. The first movement of the starting wheel puts air on all cylinder starting valves, which are opened by the starting cams in correct sequence. Further movement of the wheel cuts air off the cylinders in pairs and puts the corresponding spray valves into operating position in pairs, till finally the air is cut-off and all cylinders are running on fuel. Power control is effected by a lever which over-rides the opening of the spray valves given by the starting gear. Levers at each cylinder enable any one to be cut out in case of necessity by closing the spray valve.

The fuel pump for supplying the engine can be seen in the figure, to the left-hand side of the starting position. It is driven off the cam-shaft driving-gear in the centre of the engine and consists of a four-plunger pump with mechanically operated suction valves which can be adjusted in their action by a lever at the control position. This pump delivers oil at a pressure of about 4,000 lbs. per square inch to a pipe below the camshaft from which leads are taken, through screw-down valves, to the spray valves. The screw-down valves are for use when the strainers in the spray-valves are being cleaned. The heavy moving parts of the engine are modelled on marine practice. Large bearing surfaces are used throughout, particularly in the top ends. The slipper bearing, crank heads and main bearings are all white-metal lined, the shells of the latter being of cast-iron and the others of steel. The crankshaft is in two three-throw pieces and is forged solid. The shaft passes through glands at the ends of the crank-case and at the after end a small flywheel is fitted formed with teeth for engine turning. A small electric gear is provided for this latter service. Starting air is provided for the engine by a steam-driven compressor pumping up to 600 lbs. per square inch. The air is stored in ten riveted steel reservoirs which stand at the aft end of the engine room.

PERSONAL.—The Coventry Electrical and Engineering Company state that they have secured the Coventry agency for Wild-Barfield electric furnaces, and that they are having a furnace erected for purposes of demonstration to those interested.

LONDON ASSOCIATION OF FOREMEN ENGINEERS.—The sixty-seventh anniversary festival of the London Association of Foremen Engineers was held at Cannon-street Hotel, on Saturday, the 1st inst., when between 500 and 600 members and guests dined together. Mr. T. O. M. Sopwith presided, and there were present Lord Riddell, Sir Henry P. Maybury, Dr. Macnamara, and other distinguished visitors. Emphasis was laid in the various speeches on the most important and most successful work carried out by engineers during the war, and on the vital part which engineers could and would play during the present period of reconstruction.

THE INSTITUTE OF PHYSICS.—The incorporation of a new Institute of Physics has sufficiently advanced to place the matter, so far discussed mainly by the councils of three societies, the Faraday Society, the Optical Society and the Physical Society of London, before British scientists generally. The Institute is to be a body analogous to the Institute of Chemistry, to represent the physical profession and to strengthen the position of workers engaged in physics, as well as to form a bond between the various bodies interested in the study and application of physics. At present, it is pointed out, the physicist is hardly recognised as a member of one of the professions. Though many developments of physics have been of vital importance during the war, men engaged in important physical research would, in some cases, only be given an official status by being termed Research Chemists. The new Institute is to attend to all matters concerning the professional interests of physicists, and will, in addition to the general aims, have the following specific objects: The granting of diplomas to corporate members, who are to be of two grades, Associates and Fellows in order to attain authoritative recognition; the reduction of subscriptions for membership of the participating societies; reductions in purchasing the publications of societies of which the member of the Institute is not a member; the organisation of exhibitions of apparatus and of conferences on matters of physical interest; the provision of a common building for the libraries and meetings of the societies. The qualifications for Associateship include the passing of an examination held by the Institute or of a recognised equivalent examination, and of one year's research experience, the examination to be dispensed with in the cases of candidates with special qualifications. Candidates for Fellowship will have to show a record of five years' experience in research or in a position requiring a thorough knowledge of physics. The annual subscription of Associates is to be one guinea, that of Fellows two guineas, the entrance fees to be of the same amounts; ordinary (not corporate) members of the Institute will not pay subscriptions. The first Board consists of Sir Richard Glazebrook, F.R.S. (president), Sir Robert Hadfield, Bart., F.R.S. (hon. treasurer), Professor A. W. Porter, F.R.S. (hon. secretary), and of representatives of the councils of the three societies we mentioned; other societies may associate themselves with the Institute, which, it is hoped, will form a powerful unit in connection with any wider scheme of the federation of scientific societies. Mr. F. S. Spiers, B.Sc., of 10, Essex-street, W.C. 2, himself a member of the Board, is the Secretary of the Institute of Physics.

THE "REMCA" ELECTRIC RIVETING MACHINE.

CONSTRUCTED BY THE MADA ENGINEERING COMPANY, LIMITED, ENGINEERS, LIVERPOOL.

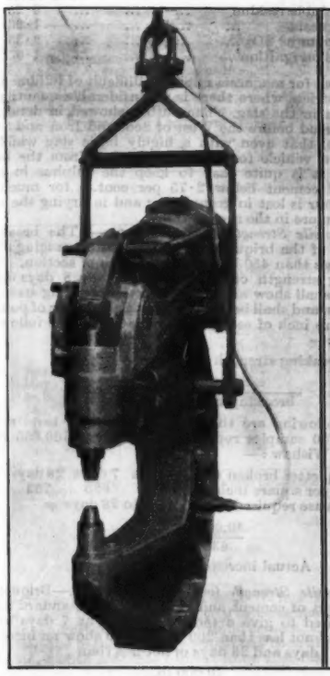
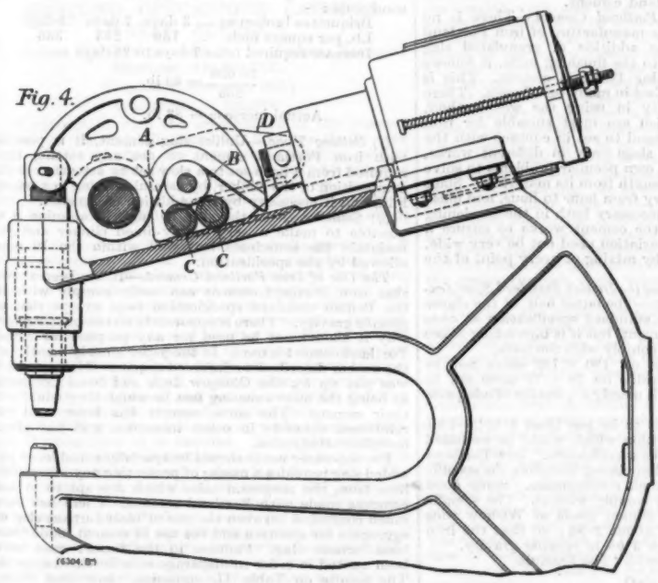
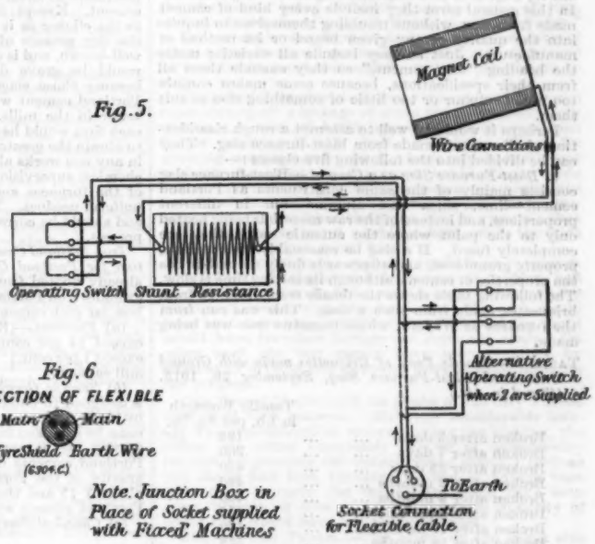


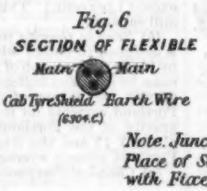
FIG. 1.

FIG. 2.

FIG. 3.







Note. Junction Box in Place of Socket supplied with Fixed Machines

MANY cases arise in practice in which it would be desirable to employ power rivetting, but in which either the amount of work to be done, or the isolated situation of the work, is such that it becomes very questionable if the installation of an hydraulic or pneumatic plant is justifiable. Most large works have now either one, or both, of these forms of power available, but many small ones have neither, and in the large works it is unusual to find the distributing mains, for either pressure water or air, carried over the whole ground. These and other circumstances make the possibility of riveting by means of electric power a matter of considerable importance in many cases and add interest to the electric riveting machine which we illustrate in Fig. 1 to 6 on this page. There are but few shops nowadays in which a supply of electric power is not available, and the ease with which mains can be run to a new position should, in many cases, make an electric riveter an attractive proposition. Even where alternative forms of power are available, the supply mains cannot, as a rule, be extended with the facility with which a cable can be run. In exposed situations the cable also, of course, has advantage over an hydraulic main in eliminating the possibility of trouble owing to freezing.

The machine which we illustrate has been patented by Mr. Edward Adamson and is manufactured by the Mada Engineering Co., Limited, of 12, Bevington-hill, Liverpool. The machine is known as the "Remca." Its general appearance is well shown in Figs. 1 to 3, from which it will be seen that it consists of a bow-frame with the operating mechanism carried on one arm. The machine may be used either vertically or horizontally, and may be suspended, as shown in Figs. 1 and 2, or fixed to a stand as shown in Fig. 3. The operating mechanism consists of a long-stroke solenoid designed so that full advantage is taken of the fact that increasing power is developed as the core approaches the end of its stroke. This gives a type of action particularly suitable for riveting, the final pressure being the maximum pressure. As will be seen from the figures, the whole arrangement builds up into a neat and compact tool, which, for portable work in particular, should be very convenient owing to the power being carried by a quite flexible connection.

The details of the operation of the machine will be understood from Fig. 4. A rocking lever A, pivoted to the frame, is attached by a pin joint to the head of the riveting ram. The rocking of the lever depresses, or lifts, the ram. The lever is operated by a roller B, which is carried between side plates D, which are secured to the end of the solenoid core. The roller B works on the inclined tail of the lever A, and it will be evident that as the solenoid core is drawn inward by the

coil the lever A will be rocked-over and the riveting ram forced down. The side plates D carry two other rollers C C, on which the roller B works, the whole arrangement giving a roller-bearing construction. After the power stroke, both the solenoid core and the rocking lever are returned to position by springs. The solenoid core spring is shown in Fig. 4, while the helical springs which return the rocking lever can be seen in Figs. 1 to 3. The electrical connections of the riveter are of a simple nature, and are shown in Fig. 5, while a cross-section of the flexible cable is shown in Fig. 6. As will be seen, an earth wire is incorporated in this, so that the frame of the machine may be earthed. The tool is, of course, operated by alternately closing and opening the switch and, if necessary, more than one operating point may be arranged for by fitting more than one switch, as indicated in Fig. 5. When a rivet is closed the pressure may, of course, be maintained while the rivet is partially cooling, simply by leaving the switch closed. Trials have shown that a $\frac{5}{8}$-in. iron rivet may be closed by a "Remca" machine with 16 amperes at 230 volts, the time from closing the switch to opening it being 3 secs. On this basis one Board of Trade unit would suffice for dealing with 300 $\frac{5}{8}$-in. rivets. The riveters are made to deal with rivets from $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. diam. and with various depths of gap.

IRON PORTLAND CEMENT.

*Iron Portland Cement, with a Classification of Cements made from Blast-Furnace Slag.**

By EDWIN H. LEWIS, Wishaw.

THREE papers dealing with the manufacture of cement from blast-furnace slag have been read before the Institute by C. de Schwarz. In the first, in 1900, he described a method of making Portland cement in shaft kilns. The second, in 1903, gave details of various cements, and among others of Portland cement made in rotary kilns, and iron Portland cement. The third paper, read in 1908, referred to various uses of blast-furnace slag, including the manufacture of cement.

Many different cements can be made from blast-furnace slags, the quality of which can vary as much as the methods of manufacture. There is at present a great demand for cement, and a number of ironmasters are thinking of using their slag for its production. In some cases they have it in their power to produce an article equal or superior to London Portland cement. Much of the cement made from slag in the past fell far below this standard, and consequently there is a great prejudice among engineers and architects against "slag cement." In this general term they include every kind of cement made from slag, without troubling themselves to inquire into the quality of any given brand or its method of manufacture. Just as they include all varieties under the heading "slag cement," so they exclude them all from their specifications, because some makes contain too much sulphur or too little of something else to suit them.

Perhaps it would be well to attempt a rough classification of all cements made from blast-furnace slag. They can be divided into the following five classes :—

1. *Blast-Furnace Slag as a Cement.*—Blast-furnace slag consists mainly of the same constituents as Portland cement—lime, silica and alumina—but in different proportions, and instead of the raw materials being heated only to the point where the eutectic melts, they are completely fused. If a slag be reasonably high in lime, properly granulated, and afterwards finely ground, it has the properties of cement, although its setting time is slow. The following table shows the tensile tests obtained from briquettes made from such a slag. This was run from the furnaces at Wishaw, where hematite iron was being made.

TABLE I.—*Tensile Tests of Briquettes made with Ground Granulated Blast-Furnace Slag, September 29, 1915. (Stored in Air.)*

	Tensile Strength in Lb. per Sq. In.
Broken after 3 days	195
Broken after 7 days	300
Broken after 28 days	430
Broken after 2 months	480
Broken after 4 months	480
Broken after 6 months	615
Broken after 12 months... ...	470
Broken after 18 months... ...	528
Broken after 2 years	666
Broken after 3 years	765
Broken after 4 years	807

The slag contained :—

	Per Cent.
Lime	49·4
Silica	30·5
Iron oxide and alumina	16·6
Magnesia	2·3
Sulphur	2·41

2. *Slag Elements.*—Under this head could be included those cements which are or have been made from war granulated slag and lime, finely ground together, with or without the addition of small quantities of other salts. Numerous papers have been published giving descriptions of such cements. Generally speaking, they are quite useful, and the cost of manufacture is relatively low. But they cannot, and should not, be compared with Portland cement. As the slag is not reburned, the sulphur contents are usually high. The high-limed slags, which have the most cement-like properties, generally contain most sulphur. It is such cements that have created amongst engineers the great prejudice against any cement in which slag has been used as a raw material.

3. *Portland Cement.*—The British standard specification for Portland cement defines it as "manufactured by intimately mixing together calcareous and argillaceous materials, burning them at a clinkering temperature and grinding the resulting clinker, so as to produce a cement capable of complying with this specification." "No addition of any material shall be made after burning other than calcium sulphate or water, or both, and then only if desired by the vendor and not prohibited in writing by the purchaser." This definition can be satisfied by using slag and limestone in exactly the same way as the chalk and mud of the Thames and Medway are used, or any materials whatever which give the same proportions of lime, silica and alumina. The manufacture of such cement is carried on by the Universal Portland Cement Company, in America, from blast-furnace slag, and the process was described by W. M. Kinney.*

4. *Improved Slag Cement.*—Some makers, finding that the slow and uncertain setting of the cement made from ground slag and lime was a serious disadvantage, have made a rather better article by adding to granulated slag a proportion of Portland clinker burnt from a mixture of slag and limestone. Such an addition improves the setting time and strength of the cement and reduces the quantity of sulphur, without adding very seriously to the cost.

5. *Iron Portland Cement.*—If a certain quantity of properly granulated slag of the right chemical composition be added to Portland clinker, during grinding, the strength of the cement can be increased. The quantity of slag which gives the greatest increase of strength will naturally vary with the composition of the slag and clinker. Such a cement might even be called an improved Portland cement. The amount of the improvement possible to some well-known cements, both for neat cement tests and sand tests, was shown by Mr. E. Deny and the present author in a paper read before the Faraday Society on January 14, 1918, and the subsequent discussion.† In Germany the Iron Portland cement makers and the Portland cement makers have agreed that such cements shall be sold under the name of Iron Portland cement, provided that the quantity of slag added to the clinker shall not exceed 30 per cent. of the whole. It is by making iron Portland instead of the inferior slag cements that ironmasters can break down the prejudice existing to-day against all cements made from slag; for they will then be making an article which may excel in quality the best Portland cement.

Manufacture of Iron Portland Cement.—There is no need here to describe the manufacture of iron Portland cement. Except for the addition of granulated slag to the clinker as it goes to the finishing mills, it follows the dry process of making Portland cement. This is well-known, and is described in many text-books. There would be grave difficulty in using the wet method, because those slags which are most suitable for iron Portland cement would tend to set in contact with the water in the mills. As slags vary in different works, each firm would have its own peculiar problems to solve to obtain the greatest strength from its materials. Slags in any one works also vary from hour to hour, and close chemical supervision is necessary both in the burdening of the furnaces and in the cement works to ensure a uniform product. The variation need not be very wide, and should be corrected by mixing at every point of the process.

Iron Portland Cement and the British Standard Specification for Portland Cement.—The latter half of the clause already quoted from the standard specification at once excludes iron Portland cement, but it is interesting to see how far such cement can comply with the tests.

(*a*) *Fineness.*—(Residue on 180 × 180 sieve not to exceed 14 per cent.; residue on 76 × 76 sieve not to exceed 1 per cent.) This is merely a question of adequate mill capacity.

(*b*) *Specific Gravity* (not to be less than 3·10).—This is designed to detect addition which would be excluded by the first paragraph of the specification. Iron Portland must be excluded under that clause, therefore the specific gravity test is not of much consequence. Some good Portland cements do not comply with it. The specific gravity of the Portland clinker made at Wishaw runs about 3·15 and the slag about 2·85; so that the iron Portland cement averages 3·06 in specific gravity.

(*c*) *Chemical Composition.*—"The formula

$$\frac{CaO}{SiO_2 + Al_2O_3}$$

when calculated in chemical equivalents, shall be not greater than 2·85 nor less than 2·0."

The average of 290 works analyses of the iron Portland cement made at Wishaw shows :—

	Per Cent.
CaO	59·58
SiO_2	25·03
Al_2O_3	11·04
Fe_2O_3	1·07

So that the hydraulic modulus :—

$$\frac{\frac{59\cdot58}{56}}{\frac{25.03}{60} + \frac{11.04}{102}} = 2.02$$

"The percentage of insoluble residue shall not exceed 1·5 per cent.; that of magnesia shall not exceed 3 per cent.; the total sulphur content calculated as SO_3 shall not exceed 2·75 per cent. The total loss on ignition shall not exceed 3 per cent." The average figures for the cement made at Wishaw are :—

	Per Cent.
Insoluble residue	0·25
Magnesia	1·96
Sulphur as SO_3	2·35
Loss on ignition	1·0

The test for magnesia might be difficult of fulfilment in some districts where there is a considerable quantity of magnesia in the slag. The author showed in detail, in a paper read before the West of Scotland Iron and Steel Institute, that even with a highly basic slag which is used as a vehicle for removing sulphur from the blast furnace, it is quite easy to keep the sulphur in iron Portland cement below 2·75 per cent.; for much of the sulphur is lost in granulating and in drying the slag but still more in the rotary kiln.

(*d*) *Tensile Strength* (neat cement).—"The breaking strength of the briquettes at 7 days after gauging shall be not less than 450 lb. per square inch of section. The breaking strength of the briquettes at 28 days after gauging shall show an increase on the breaking strength at 7 days, and shall be not less than the number of pounds per square inch of section arrived at from the following formula :—

$$\text{"Breaking strength at 7 days} + \frac{40{,}000 \text{ lb.}}{\text{breaking strength at 7 days."}}$$

The following are the average results of tests made from 8,700 samples representing the first 100,000 tons made at Wishaw :—

Briquettes broken at ...	3 days	7 days	28 days
Lb. per square inch ...	467	635	753

Increase required from 7 days to 28 days =

$$\frac{40{,}000}{635} = 63 \text{ lb.}$$

Actual increase = 118 lb.

(*e*) *Tensile Strength* (cement and sand).—Briquettes of one part of cement and three parts of standard sand are required to give a tensile strength at 7 days after gauging of not less than 200 lb., and to show an increase between 7 days and 28 days of not less than

$$\frac{10{,}000 \text{ lb.}}{\text{breaking strength at 7 days}}$$

The following are the average Wishaw results from sand tests :—

Briquettes broken at ...	3 days	7 days	28 days
Lb. per square inch ...	159	253	336

Increase required from 7 days to 28 days =

$$\frac{10{,}000}{253} = 40 \text{ lb.}$$

Actual increase = 83 lb.

(*f*) *Setting Time.*—Unlike slag cement, it is possible with iron Portland cement to get any setting time required from a flash set to a slow set by attention to the composition of the clinker, by careful burning in a rotary kiln, and if necessary by the addition of gypsum.

(*g*) *Soundness.*—If the slag be high in alumina it is possible to make a very highly-limed clinker and yet maintain the soundness test well within the 10 mm. allowed by the specification.

The Use of Iron Portland Cement.—It has been shown that iron Portland cement can easily comply with all the British standard specification tests except that of specific gravity. There is apparently no reason, therefore why it should not be used for any purpose for which Portland cement is used. In the paper already mentioned the author described a reinforced concrete chimney which was put up by the Glasgow Iron and Steel Company as being the most exacting test to which they could put their cement. The same cement has been used for reinforced concrete in other instances, and has given complete satisfaction.

For sea-water use it should be specially suitable, as the added slag provides a means of protecting any unsatisfied lime from the magnesia salts which are apt to attack concrete made with Portland cement. There has been much confusion between the use of blast-furnace slag as aggregate for concrete and the use of cement made from blast-furnace slag. Failures in the former case have been quoted in order to disparage iron Portland cement. The results on Table II, opposite, show that blast-furnace slag, specially the highly basic slag which is good for making cement, may be a poor material for aggregate compared to such an aggregate as steel furnace slag; but that does not affect its use for making cement. The slag used as aggregate was of the same chemical composition as that used for the cement with which the concrete was made in both cases.

Most of the results so far quoted have been obtained in the works at Wishaw. The figures in Table III, opposite, have been supplied by a well-known firm of civil engineers who have used iron Portland cement from Wishaw in the construction of a quay wall on the Clyde. They made careful tests, because like other engineers they were originally prejudiced against this class of cement, and they now own to a complete conversion.

Conclusion.—Nearly all blast-furnace slags can be utilised as raw material for making Portland cement, although in some cases a large addition of limestone would be required to increase the percentage of lime and reduce that of magnesia, &c. Only some of these slags can be used for the subsequent addition to the clinker necessary for iron Portland cement. Ironmasters who

* Paper read before the Iron and Steel Institute, May 6, 1920.

* Proceedings of the Engineers' Society of Western Pennsylvania, vol. xxv., pages 103 to 138.

† See ENGINEERING, vol. cv., page 109.

TABLE II.—CRUSHING STRENGTH OF CONCRETE (POUNDS PER SQUARE INCH).

Mixture.	Blast-Furnace Slag Aggregate.				Siemens Acid Steel Slag Aggregate.			
	3 Days.	7 Days.	28 Days.	90 Days.	3 Days.	7 Days.	28 Days.	90 Days.
1 iron Portland cement + 1 aggregate ..	2,625	3,970	7,500	8,075	3,600	4,650	6,000	5,800
1 iron Portland cement + 2 aggregate ..	1,675	2,650	4,900	5,725	3,450	4,775	7,050	6,900
1 iron Portland cement + 3 aggregate ..	1,075	1,950	3,250	4,000	3,175	4,575	5,850	7,375
1 iron Portland cement + 4 aggregate ..	—	2,325	3,200	4,300	2,450	3,450	5,375	6,750
1 iron Portland cement + 5 aggregate ..	1,200	1,600	2,625	3,750	2,850	4,125	3,750	4,850
1 iron Portland cement + 6 aggregate ..	450	1,075	2,650	2,700	2,050	2,650	4,050	4,400
1 iron Portland cement + 7 aggregate ..	775	1,375	2,150	2,225	1,637	2,650	3,000	3,050
1 iron Portland cement + 8 aggregate ..	1,150	1,475	2,700	2,600	1,325	1,750	2,700	3,200
1 iron Portland cement + 9 aggregate ..	400	1,125	2,225	1,575	800	1,175	1,975	3,050

TABLE III.—TENSILE AND COMPRESSION TESTS.

Tensile Tests.

Date.	Sample.	7 Days.	28 Days.	3 Months.	Fineness, 180×180.	Setting Time—Neat. Initial.	Setting Time—Neat. Final.	Expansion.	Specific Gravity.
	"Giscol"	Lb. per Sq. In.	Lb. per Sq. In.	Lb. per Sq. In.				mm.	
1919. Mar. 3 ..	1	231	415	475	8·5	7 mins.	45 min.	0·5	3·05
May 13 ..	3	324	426	482	7·95	30 min.	7¼ hr.	3·0	3·01
Sept. 26 ..	6	388	489	518	—	85 min.	7½ hr.	3·0	3·03
1920. Jan. 23 ..	8	291	455	—	9·07	84 min.	6¼ hr.	3·5	3·05
	"English."								
1919. May 2 ..	—	344	—	—	6·62	2 hr.	5¼ hr.	2·0	3·175
1920. Jan. 23 ..	7	266	347	—	10·46	62 min.	4½ hr.	2·0	3·10

NOTE.—This was not a test of the cement but of a particular aggregate, which was found unsuitable.

Compression Tests.

28 days. Mixture 1—1—3.

"English." Lb. per Sq. In.	"Giscol." Lb. per Sq. In.
1,146	1,189
907	983

make cement will in any case have to face opposition, and it is very much to their mutual interest that, whether they make Portland or iron Portland cement, they should maintain the highest quality which has been shown to be possible, and so convince cement users that blast-furnace slag is an excellent material for its manufacture.

GROUTING OPERATIONS, CATSKILL WATER SUPPLY.*

By JAMES F. SANBORN and M. E. ZIPSER, Associate Members, Am.Soc.C.E.

(*Concluded from page 562.*)

GROUTING IN SHAFTS.

In connection with the construction of the pressure tunnels of the Catskill Aqueduct, fifty-five shafts were sunk. Some of these are permanent, forming part of the waterway; the others were sunk only to expedite the tunnel excavation, and subsequently were closed by concrete plugs. The shafts varied in depth from 106 ft. to a maximum of 1,187 ft., the average being about 400 ft.

As in the case of the tunnels, the shafts penetrated a wide assortment of rock. With a few exceptions, however, no great difficulties were experienced in sinking them, as the rock encountered was generally sound and free from large quantities of water. In some of the shafts where the inflow of water was excessive, the rock seams were grouted during sinking in order to cut off or reduce the flow. In general, the water-bearing ground did not extend to any great depth, but was found in zones about 20 ft. to 30 ft. thick, so that, after the wet portion of the shaft was grouted and passed, no further grouting was necessary in the remainder of the shaft.

Shaft sinking is slow and expensive when large quantities of water have to be handled. The water collects in the bottom, making it troublesome to drill and to muck the broken rock, thereby delaying the work. The maintenance and operation of pumps also interferes with the excavation and increases the cost. The method of grouting water-bearing seams in a shaft during excavation, to cut off the inflowing water, has been used to some extent, although the process has been more fully developed and applied during the last few years.

The method usually adopted in grouting a wet zone is to drill a number of vertical holes in the bottom of the shaft, about 10 ft. to 20 ft. in depth and located generally from 5 ft. to 10 ft. around the periphery of the shaft. Short lengths of pipe fitted with valves are set into the drill holes, and the drilling is done through the valves which can be quickly closed if a heavy flow of water is struck.

After the holes have been drilled, grout is forced into the rock seams through them, by the usual grouting equipment. As in other grouting, a thick grout is best for filling large cavities, while a thin grout, as thin as 5 lb. of cement to 25 gallons of water, is necessary during the early stages of the injection of the grout, in order to make the cement carry as far as possible into the fine seams and avoid the plugging of the seams close to the drill hole. The matter of adjusting the consistency of the grout is important to insure success. After the grout has set up, and the water is cut off, sinking is resumed, using light shots to avoid opening up new fissures in the rock. The method of grouting outlined was used in sinking through wet ground in several of the Catskill shafts. The sinking in these cases would have been much more difficult, slower, and more expensive, had pumping alone been depended on.

Shaft 4, Rondout Pressure Tunnel.—This shaft, 500 ft. deep, was one of the construction shafts for the Rondout Pressure Tunnel. It was rectangular in shape and was timbered as it was sunk. This was the wettest shaft on the Catskill work, and the grouting of the water-bearing strata encountered in its excavation was very successful in cutting down the inflow of water, although pumping had to be carried on continuously during the sinking as additional wet seams were struck. A detailed description of the sinking of this shaft has been given in a paper* by John P. Hogan, M.Am.Soc.C.E.

Preliminary exploration by borings showed that the shaft would penetrate Binnewater sandstone and High Falls shale at a depth of about 200 ft. The rock cores from these beds showed a very porous condition, and pumping experiments indicated that the rocks were freely water-bearing. It is probable that considerable time would have been saved and expensive pumping eliminated during the sinking of the shaft if 4-in. holes had been drilled close together around the perimeter of the shaft when the water-bearing strata were reached, and the rock thoroughly solidified by injecting grout into the seams through these holes. The shaft could then have been excavated in the dry.

However, the drilling of the large holes necessary to insure the complete success of the grouting under such a method would have been a slow and expensive procedure, and experience at the time did not recommend it as the best method of meeting the situation. The handling of water by pumping was familiar to the shaft-sinkers who kept on drilling and mucking until stopped by an excess of water, even though the shaft was flooded several times before the grouting was done.

The shaft was dry until a depth of 215 ft. was reached, when the water-bearing Binnewater sandstone was encountered. At a depth of 260 ft., the flow had increased to 225 gallons per minute. While drilling the next round of holes, one of the holes struck such a strong flow that the men had to leave hurriedly, and the shaft was flooded to within 70 ft. of the top. The maximum flow of water entering through the drill holes in the bottom was estimated to be approximately 600 gallons per minute.

After a long delay, the shaft was pumped out, and the hole in the bottom was plugged with a 2-in. nipple and gate-valve. Drilling was then resumed in the bottom, through valves on pipes set into the drill holes, the valves being shut as water was encountered. On account of trouble with the pumps and the suction and discharge pipes, the shaft was again flooded twice in succession and each time recovered.

The last holes drilled in the bottom indicated that for the next 8 ft. the ground to be excavated was very porous, with open seams as wide as 8 in. It was feared that, when the next shot was made, there would be such a great inflow of water as to flood the shaft again. It was then decided to attempt to cut off the water by grouting the water-bearing seams.

For this purpose, twenty-seven vertical holes were drilled from 14 ft. to 20 ft. deep, around the bottom of the shaft, each hole being fitted with a pipe and valve. A total of about 3,000 bags of cement was forced into these holes. At first, the grout leaked back into the shaft, but after some experimenting, the seams were finally clogged by mixing bran, oats, and ground horse manure with the cement. This grouting was so successful that it was decided to attempt to grout the remainder of the water-bearing strata in a single operation down to the top of the Shawangunk grit, a hard quartz conglomerate encountered in sinking the lower portion of the shaft. Six diamond drill holes, 1 in. and 2 in. in diameter, were drilled around the perimenter of the shaft for a depth of 100 ft. The holes were grouted under a pressure of 275 lb. per square inch, but only 175 bags of cement could be forced in. After further delays, due to pump troubles, sinking was resumed. In the first 15 ft. excavated, numerous seams well filled with grout were encountered; the maximum thickness of the grout was 8 in., in an irregular open bed of sandstone. The leakage into the shaft at this time was 225 gallons per minute, which increased to 350 gallons per minute at a depth of 280 ft. The water continued to increase in quantity to 525 gallons per minute, at a depth of 320 ft., and was strongly charged with H_2S gas, which attacked the men's eyes and caused abrasions to develop into sores.

In the meantime, the pumps continued to give trouble and with the shaft filled with no less than ten of them at one time, and with air and discharge lines, it was almost impossible to carry on the sinking operations. Due to the breaking down of one of the station pumps in the shaft, the latter was flooded for the sixth and last time. After it was again unwatered, a large pump chamber was excavated in the side at a depth of 310 ft., and three steam pumps having a combined capacity of 1,050 gallons per minute were installed therein.

Sinking was then resumed (a pilot drill hole being kept well below the bottom) and all seams were grouted, none of them taking more than 50 bags of cement, until the grit was reached. At the contact with the grit, an additional flow of 125 gallons per minute entered through an old drill hole, increasing the total inflow to 850 gallons per minute. The flow was cut off by injecting 350 bags of cement under a pressure of 275 lb. per square inch. All water-bearing seams in the grit were grouted, the maximum quantity of cement used at any point being 100 bags. When the bottom was reached, the total inflow into the shaft was 610 gallons per minute.

The method of grouting used in this shaft was, in general, as follows: A 2-in. pipe provided with a long nipple and a gate-valve was driven into the drill hole as far as possible. To obtain a tight packing around the pipe, wooden wedges, oakum and cement were freely used, and horse manure mixed with the cement was also frequently used to clog the openings. A battery of four to six Canniff grout tanks was set up at the top of the shaft and connected with the hole by a 2½-in. pipe. The air pressure for grouting varied from 100 lb. to 275 lb., the former being obtained from the main air line, and the latter from a small Westinghouse "booster." A thin mixture was used at first, and the quantity of cement was increased gradually; if this mix continued to flow freely, sand was added until the pipe began to clog.

The grouting in this shaft was very successful, at one time cutting off a leakage of more than 400 gallons per minute. A total of 1,163 barrels of cement was used in the grouting in the shaft. The holes drilled for grouting were generally 30 ft. deep, which depth was probably too great, as the grout would fill the wide horizontal seams, while the finer seams, out nearer the bottom of the drill holes, would only be grouted for perhaps a few inches from the holes, due to the fact that in these seams the grout would set hard, while the wide seams were taking grout freely.

It is believed that the grouting would have been even more effective if shallower holes, about 12 ft. deep, had been drilled, as such holes would have cut a smaller number of seams, with the result that the rock would have been more thoroughly impregnated, and the grout would have travelled farther out from the shaft. On other work the best results have been obtained by alternately drilling and grouting using shallow holes for the purpose.

City Tunnel Shafts.—All the shafts of the City Tunnel were lined with concrete. Although considerable leakage was encountered in several during the sinking, the inflow was either completely cut off or considerably reduced by grouting the water-bearing seams. If these wet shafts had been timbered instead of having been lined with concrete, the excavation would have been more difficult on account of the excessive quantity of water that would have had to be handled.

Shaft 4, City Tunnel.—This shaft, on the south side of Jerome Park Reservoir, was sunk to a depth of 242 ft. in Fordham gneiss. The rock was sound, and the shaft was dry until a depth of 150 ft. was reached, when the flow of 150 gallons per minute was encountered while drilling holes in the bottom. In a short time, the quantity diminished to a constant flow of about 50 gallons per minute. After the shaft, which had been flooded, was pumped out, the drill holes were plugged and the concrete shaft lining was placed to within a few feet of the bottom.

The drill holes were then grouted under an air pressure of from 100 lb. to 225 lb. per square inch, using a mix of about 16 lb. of cement to 1 gallon of water. A total of 46 bags of cement was used in this grouting, and the leakage was entirely cut off. Water under a pressure of 70 lb. per square inch was also struck at a depth of 181 ft., and the flow at this level too was cut off by grouting.

Pilot holes, 14 ft. deep, were then drilled and all struck water, which in some cases washed 1-in. fragments of rock from the drill holes, indicating the presence of a disintegrated seam. These holes were grouted, but they took very little cement. The shaft was sunk another

* Paper read before the American Society of Civil Engineers, February 4, 1920.

* "Sinking a Wet Shaft," *Transactions*, Am. Soc. C.E., vol. lxxiii, page 398.

5 ft. without increase of water. The bottom of the shaft was then in disintegrated rock well grouted.

The next step was to drill a large number of vertical holes, 18 in. apart and 16 ft. deep, around the periphery of the shaft. The holes were grouted, one at a time, each hole taking about two batches of grout, except some at one side of the shaft through which the leakage was about 100 gallons per minute. The water from these holes could not be shut off, and the leakage was taken care of by pumping. As the shaft was deepened, no increase of flow was encountered, and sound rock was reached at a depth of 200 ft.

The water-bearing ground below the 181-ft. depth showed a crushed fault zone with a maximum thickness of 8 ft. on one side, below which the rock was disintegrated to a depth of 4 ft. A total of approximately 1,000 bags of cement was used in grouting this stretch, and although the disintegrated ground was found to be well impregnated with grout, the flow of water could not be entirely cut off. Thick grout was generally used, but it is believed better results might have been secured by the use of thin grout. After the shaft had been completely lined, the water-bearing seams were grouted through pipes set in the lining, and the leakage was reduced to 3 gallons per minute.

Shafts 20 and 21, City Tunnel.—Shaft 20, 750 ft. deep, in the lower part of Manhattan Island, was excavated in Fordham gneiss which was generally dry. No trouble with water was experienced until a depth of 425 ft. was reached, when a flow of 30 gallons per minute was struck in the drill holes in the bottom of the shaft. Deep holes were drilled, pipes inserted, and a concrete blanket 2 ft. thick was placed over the bottom of the shaft. Grouting was started too soon, before the concrete had set hard, and it was necessary to add another 2-ft. layer of concrete. After a lapse of 48 hours, the holes were grouted under a pressure of 300 lb. per square inch, and the water was cut off. No further trouble was had in excavating the remaining depth in the shaft.

Shaft 21 was sunk in granodiorite to a depth of 757 ft. at the East River, in the lower part of Manhattan Island. The rock was hard and seamy, and wet zones were encountered about every 60 ft. or 80 ft. The wet seams were grouted successfully in every case. A concrete blanket was placed over the seam to be grouted, as at Shaft 20, to retain the grouting pressures, and the results were satisfactory. The concrete lining in the shaft was placed in stretches of about 50 ft., as the sinking progressed, and any water entering through the grout pipes set in the lining was grouted off, in order to keep the bottom of the shaft as dry as possible.

Shafts 22 and 24, City Tunnel.—Shaft 22, in the Borough of Brooklyn, was sunk through gneiss and granodiorite. Only small quantities of water were handled, except at Elevation — 430, where a flow estimated to have been 200 gallons per minute, was encountered in a drill hole. The flow was controlled by inserting a pipe provided with a valve in the hole, after which other holes from 5 ft. to 20 ft. deep were drilled to locate the extent of the water-bearing area, which was found to be on one side of the shaft.

The first attempt at grouting was unsuccessful, due to the large number of seams. A concrete blanket was then placed around two of the pipes, in the wet portion of the shaft, and the water was cut off by grouting under a pressure of 350 lb. per square inch, only six days after it was first struck. Subsequent excavation showed that seams not more than $\frac{1}{8}$ in. wide were filled completely with cement. These seams were sharply defined cracks in the hard rock and were cut by the drill holes in such a manner as to provide good circulation of the grout, with the result that the grouting was successfully completed in a few shifts.

The granodiorite and gneiss through which Shaft 24 was sunk was blocky and more or less crushed. Little trouble was encountered in handling the water in the shaft, except in a stretch of 40 ft. at a depth of about 300 ft., where a flow of 240 gallons per minute was struck by one of the drill holes. The shaft was flooded, and it became necessary to instal a large pumping plant to unwater it. After it was pumped out the hole through which the water issued was plugged, and 14 holes were drilled around the periphery of the shaft, varying in depth from 7½ ft. to 17½ ft. Through pipes fitted into these holes, 55 cub. yards of grout was forced into them under pressures as high as 325 lb. per square inch.

The grouting of the wet seam caused the water to rise in the rock and flow from the smaller seams above. Holes were drilled into these seams, and grout, under low pressure, was forced into them, wedges of soft wood being driven into the seams where necessary to prevent the grout from escaping into the shaft. The leakage from these seams was reduced from 50 gallons to 15 gallons per minute.

On resuming excavation it was found that the seam which yielded the large flow had been successfully grouted and gave no further trouble, but, after the smaller seams above had been closed the rock in the shaft scaled so badly that it was necessary to suspend sinking and place the concrete lining. The leakage remaining was taken care of by pipes set in the concrete and subsequently grouted.

Grouting behind Caissons, City Tunnel.—Before ledge rock was reached the six southerly shafts of the City Tunnel had to penetrate through a deposit of water-bearing sand, varying in depth from 43 ft. to 150 ft. The earth portions of these shafts were excavated by reinforced concrete caissons sunk by compressed air.

In order to effect a tight seal at the surface of the rock the caissons were sunk from 2 ft. to 5 ft. below the lowest point of sound rock around the cutting edge, and the space between the caisson and the rock was grouted through pipes set in a concrete bench on which the cutting edge of the caisson was sealed. Pipes were also placed through the concrete above the bottom of the caisson for the purpose of grouting the sand surrounding the caisson. The work was successful, as the leakage from the seal, after taking off the air, was only 7 gallons per minute at the deepest caisson, that at Shaft 23, where the hydrostatic head was more than 100 ft., and, subsequently all this leakage was grouted off. (See Fig. 7.)

The experience in grouting the sand behind the caissons indicated, as found on other work, that little can be done to consolidate a mass of sand by attempting to fill the voids in it by grouting, but very good results can be obtained by grouting in filling voids due to loss of ground.

Grouting Closures of Construction Shafts.—The construction shafts, which were sunk solely to expedite the excavation of the pressure tunnels, were closed by filling them, for a depth of about 50 ft. above the waterway of the tunnel, with concrete. These shafts were rectangular in shape, measuring about 10 ft. by 22 ft., and were timbered. Before the concrete plug was placed the timbering in the bottom 50 ft., was removed, and the concrete was placed solidly against the rock.

It was realised that the concrete in the plug might shrink and leave a space between it and the rock through which the water from the tunnel would escape to the surface. In order to permit the filling of the shrinkage space, grouting channels were left entirely around the shaft at the top of each lift or at vertical intervals of about 10 ft. to 15 ft. These channels were formed by placing sheets of tin or sheet iron around the shaft, the bottom edges of the tin being left in the fresh concrete, while the upper edges were wedged tightly against the rock. (see Fig. 8.)

Each grouting channel was provided usually with three 2-in. pipes set in the concrete; one, acting as a vent or drain pipe, extended down to the tunnel, and two were carried up to the top of the plug. The channel was kept from clogging during the placing of the concrete by flushing it with water through the pipes leading to the top of the plug. After the concrete had set and shrinkage had taken place, the channels were grouted from the top of the plug, beginning with the lower one and working up.

The usual procedure before injecting the grout was to apply air pressure to each of the two pipes leading up from the grouting channel. While one pipe was being blown out the other was kept closed so as to wash any water or accumulation through the down drain pipe into the tunnel. Neat cement grout was then forced into one of the pipes until it showed at the vent pipe in the tunnel; the vent was then closed, and grouting was continued until the grout flowed from the top of the other up pipe. The latter was then closed and grouting continued until no more grout could be forced in under a pressure of 300 lb. per square inch. The high pressure was then applied to the other up pipe, and the process was continued until all the channels were grouted.

There is some question as to whether grout can be forced into the fine shrinkage space that may develop between the concrete plug and the rock. In Shaft 3, Rondout pressure tunnel, where it was necessary to excavate the plug in connection with the repair work in the tunnel, there were no indications of any layer of grout between the concrete and the rock. The concrete was found to adhere closely to the rock surface. Grouting pans are of advantage, however, in protecting the concrete from water seeping into the shaft. If the water is not collected it will find its way through the concrete, or between the concrete and the rock, resulting in injury to the concrete or to the bond.

In Shaft 6, Rondout pressure tunnel, 63, 45 and 53 batches of neat cement were forced into the lower, middle and top grouting channels, respectively, of the shaft plug. The total volume of grout injected, namely, 161 batches, corresponding to about 200 cub. ft. of grout, exceeded the estimated volume of space in the grouting channels, so that it is believed that some of it penetrated into the rock seams. There was also indication of this during the high-pressure grouting of the top channel. Grout appeared in the rock seams above the plug and also at the top of the plug at the contact between the concrete and the rock, 19 ft. above the top channel. The grout leaks clogged up as the air pressure was continued.

In grouting many of the construction shaft plugs, no trouble was experienced, after connecting to a pipe leading to a grouting channel, and closing all other vents, to force air either through the rock itself or through the contact between the concrete and the rock. The fact that the air pressure could be kept at 100 lb. during the previously mentioned test, or raised to a higher pressure, showed that the seams and openings were very small.

It is important while removing the shaft timbering in connection with the placing of the concrete plug, to take down all loose rock and place the concrete against the solid rock. It is possible that the passage of air occurring during the tests previously noted, took place through loose rock seams instead of between the concrete and the rock. Not only should loose rock be removed, but also all rock that sounds "drummy" when pounded.

The concrete plugs at the bottom of the construction shafts proved to be very tight against outward leakage.

Grouting Closures in Riser Valve Shafts.—The City Tunnel shafts, through which water is supplied from the tunnel to the valve chambers at the top of the shafts, are provided with riser valves, which are about 100 ft. below the top of sound rock. These valves are designed to close automatically if a break occurs in the valve chamber or in the street main. Below them the water way is a 14-ft., or larger, concrete-lined shaft, and above them, the 4-ft. or 6-ft. riser is a mortar-lined steel pipe, embedded in a solid plug of concrete forming the shaft closure. The concrete plug was placed inside of an outer shaft lining of concrete, the latter having been placed during the sinking of the shaft.

Grouting rings or channels were formed at frequent intervals, when placing the plug concrete, to permit the grouting of the shrinkage space between the new and the old concrete. These channels were grouted after the concrete had been in place a sufficient length of time to ensure complete shrinkage.

The procedure in Shafts 15 and 16 was typical of the practice in the City Tunnel shafts. In these two shafts three grouting channels were formed between the concplete plug and the outer lining, the lowest one being about 5 ft. above the point where the plug started, and the others about 10 ft. and 20 ft. respectively, above the bottom one. The channels were formed at the end of the day's work by placing segmental timbers of 4 in. by 4-in. cross-section in the top of the green concrete, around the perimeter of the plug.

Two 2-in. pipes, placed diametrically opposite, were carried from the bottom of the plug to the bottom of each grouting channel. Before starting to place the next lift of concrete the channel was covered with sheet iron bent against the outer lining and covered with a sloping layer of stiff concrete about 1 ft. thick. The latter protected the sheet iron and kept it from being displaced.

After the concrete plug had set six weeks, the channels were grouted. The general procedure in each case was to blow out the pipes and channels with compressed air at pressures of 50 lb. to 60 lb., after which water was forced through, and, finally, grout was injected under pressures up to a maximum of 150 lb. per square inch. The grout used varied from a mix of one volume of cement to eight volumes of water to one of equal volumes of cement and water. The experience at these shafts showed a slight passage of water and grout from channel to channel, but no evidence of leakage showed round the plug at the top of the shaft.

In Shaft 24 of the City Tunnel, four grouting channels were provided in connection with the placing of the concrete plug which is 197 ft. deep and 24 ft. in diameter. To each of the two lower channels three 2-in. pipes were carried from the shaft below the plug, and from the two upper channels, three pipes were carried to the top of the plug. Compressed air was forced into the pipes of the lower channels before any grouting was begun. The air circulated freely between the plug and the outer lining, appearing at the surface.

The bottom channel was grouted first, the grout being forced into the pipes until they refused it under 300 lb. pressure. The grout from the lower channel flowed upward into the next channel and its pipes, but reached the top of the plug through the pipes of the upper channels. Connection was made to each pipe, the lower channels being completely grouted before the upper ones were begun.

The results obtained at all the City Tunnel shafts have been very satisfactory, as there has been no leakage into any of the chambers at the top of the shafts. At some of the shafts, the pressure of the water at the level of the chamber floor is about 110 lb. per square inch.

GROUTING UNDER THE FOUNDATIONS OF DAMS AND DYKES.

Grouting Seams in Rock under Olive Bridge Dam.—The masonry portion of this dam is about 1,600 ft. long, and rises to a maximum height of 210 ft. above the bed of Esopus Creek. The bluestone layers underneath the creek were excavated to sound rock at a maximum depth of about 25 ft., and, in addition, a cut-off trench about 20 ft. wide was excavated, to a maximum depth of 40 ft., across the creek channel just below the upstream edge of the dam. Below the top layer of bluestone, alternating layers of slate, shale and bluestone were found, the beds varying in thickness from 1 ft. to 15 ft.

Before excavation for the dam was started, the rock underlying the foundations was explored by means of 15 diamond drill borings from 40 ft. to 100 ft. deep, put down in the bed of the creek and the adjacent rock sides. The holes were tested by hydrostatic pressure tests for the purpose of locating the position and permeability of the seams in the rock. These investigations showed two definite planes of leakage at depths of 40 ft. and 60 ft. below the bed of the creek.

To prevent the flow of water through the open seams, a total of 217 holes, 2½ in. in diameter, were drilled to about 1 ft. below the seams for the purpose of grouting them. The lower seam was reached by a row of 45 holes, spaced about 5 ft. apart, drilled from the bottom of the cut-off trench. For grouting the upper seam, seven rows containing 172 holes, also spaced 5 ft. apart, were drilled from the bottom of the excavation down-stream from the cut-off trench. A model was made, showing the position of the grout holes and the water-bearing seams, and was found to be useful in connection with the subsequent grouting.

A 3-ft. length of 2-in. wrought-iron pipe, the lower end of which was chipped with a chisel and wrapped with jute, was driven into the tops of the holes until the jute became firmly wedged and made a tight joint. The pipe was then wedged fast at the top with two small iron wedges, and the annular space between it and the sides of the drill hole was filled with grout, thus sealing the pipe in the hole. If water was flowing from the drill hole, the iron wedges and the grout were omitted, and dry cement was rammed into the top of the hole outside the pipe.

Sections of pipe of convenient length were successively screwed to the tops of the grout pipes so as to keep them always above the top of the cyclopean masonry as the latter progressed, until the holes were grouted. After the surface of the rock was covered by a sufficient weight of concrete masonry to overcome the possibility of lifting or blowing out by hydrostatic pressure, the tops of the grout pipes were connected to a Cockburn grouting machine of about 4 cub. ft. capacity, and grout was forced into the hole by an air pressure of from 25 lb. to 90 lb. per square inch. The grout generally used was mixed in equal volumes of neat cement and water.

The grouting extended over a period of about one year and was done at any convenient time after the concrete had attained a height of 10 ft. or more. The 45 holes extending to the lower seam took a total of 251 cub. ft. of grout, of which it was estimated that 175 cub. ft. entered the seam. The 172 holes drilled to the upper seam received a total of 1,118 cub. ft. of grout, of which it was estimated that 925 cub. ft. entered the seam.

The quantity of grout forced into any hole varied from 0 cub. ft. to 198 cub. ft., and only about 10 per cent. of the total number of holes took an appreciable quantity. The maximum distance through which grout was forced, making its appearance in other pipes, was 70 ft.

A number of experiments were made in connection with the grouting, which are of interest. Grout was forced under a pressure of 25 lb. per square inch into a hole drilled about 15 ft. back from the edge of the cut-off trench, and appeared on the face of the trench from a horizontal seam about 6 in. below the top. Several months later, the rock covering this seam was barred and wedged off, and the seam appeared to be well filled with cement which was set hard.

Grout was also forced into a drill hole about 6 ft. back from the face of the cut-off trench, through two seams to the face of the trench. Two days later the rock was barred off, exposing the seams which were found to be well filled for a distance of 4 ft. in every direction from the hole, and partly filled 2 ft. farther out.

Grouting at Woodstock and Glenford Dikes.—These two structures close the gaps between the hills forming the Ashokan Reservoir. The dikes consist of rolled embankments with centre concrete core walls which, with the exception of short portions, were carried down to ledge rock. In the vicinity of the dikes, the rock is overlaid with a cover of clay and gravel, varying from 1 ft. to 30 ft. in depth.

As the East Basin of the reservoir filled, it was observed that some seepage was taking place underneath the dikes, which increased as the water level in the reservoir rose. Although the loss of water was not serious, it was considered advisable to take measures to stop the seepage and to improve the character of the foundations. To determine to what extent this might be accomplished, it was decided to grout a portion of the foundation of the Woodstock Dike.

Operations were limited to a length of 379 ft., the total length of the dike being approximately 2,500 ft. Holes were drilled, spaced about 12½ ft. apart, on the centre line of the dike where the core wall extended to rock, and on a 5-ft. or 6-ft. off-set line up-stream from the centre line, where the core wall was not carried down to rock. Thirty-five holes were drilled, their total depth through the embankment and earth cover aggregating 426 linear ft., while the depth of the core-borings totalled 717 linear ft.

Where the holes were on the centre line of the dike, a 4-in. casing was driven to the core wall, a distance of approximately 9 ft. A 3-in. hole was then drilled into the core wall to a depth of 2 ft., into which a 2½-in. casing was driven and grouted, giving a tight seal. The 4-in. casing was then withdrawn. For the holes up-stream from the core-wall a 2½-in. casing was driven to rock. The rock was chopped out to a depth of from 4 in. to 24 in. and the casing was driven tightly into it.

The core-borings were made with an "A" bit, which cut a hole of approximately 1⅞ in. diameter. The rock encountered was bluestone, varying from a coarse stone of good quality to a very fine-grained stone. In general, the holes averaged 40 ft. in depth, 20 ft. of this being in rock. Tests made by pumping water into the holes showed loss of water at practically all those drilled in rock, the maximum quantity that could be pumped into a hole without accumulating pressure, having been 66 gallons per minute.

On the completion of the drilling, the holes were grouted. Two Cockburn-Barrow grout machines were used to mix the grout, discharging into a wooden box, from which it was pumped by a Douglas hand grout pump into the hole to be grouted. The mix varied in consistency from ½ bag of cement and 40 gallons of water to 5 bags of cement and 40 gallons of water. The general method of procedure was to attach the grout pump to a hole and continue pumping in grout as long as the hole would take it. In the majority of cases, the grout did not show in adjacent holes. In one instance, however, it appeared in a hole 37 ft. distant from the one grouted.

On the completion of the grouting of the rock, the casing was first pulled about 12 in. to 18 in. and grout was then pumped in, keeping the pressure at a maximum of 7 lb., except that after work had been done on a hole and then resumed after an interval, a slightly higher pressure was used for a short time. When the hole would take no more grout, the casing was pulled another 18 in. and the grout applied once more to refusal. This procedure was continued, alternately pulling casing and grouting, until the casing had been raised so that the bottom was at the elevation of the flow line.

The maximum quantity of grout forced into a hole in the rock was 1,078 bags of cement and the minimum 13 bags. The maximum quantity forced into a hole in the earth cover above the rock was 496 bags and the minimum 20 bags. A total of 1,861 barrels of cement was used in this experimental grouting. It resulted in an appreciable reduction in the amount of seepage for the portion of the dike treated. Measurements made soon after the completion of the grouting, indicated a reduction of approximately 50 per cent. in the amount of seepage.

In view of the satisfactory results obtained in grouting the experimental section, it was decided to grout the foundations of the Woodstock and Glenford Dikes for their entire lengths, except a few sections which it was thought unnecessary to treat.

A modification was made in the procedure originally followed. Where the core wall was founded on rock, the holes were drilled in two rows, 2 ft. apart, spaced about 20 ft., centre to centre, in each row, the holes being staggered. In the Woodstock Dike, the holes were drilled through the core wall and into the rock, the method of sinking and sealing the casing being the same as that described in the experimental work. At the Glenford Dike, it was impossible to drill holes through the core wall because of the location of the Ulster and Delaware Railroad on that dike; the casings, therefore were sunk up-stream from the core wall, with the same spacing as described previously.

For the portions of the Woodstock Dike where the core wall was not carried to rock, holes were placed on offsets and spaced 5 ft. apart; 4-in. casing was sunk to rock, and, at alternate holes, 2½-in. casing was placed inside the 4-in. casing and securely sealed into the rock. The holes through the core wall and into the rock were 2 $\frac{1}{16}$ in. in diameter instead of 1⅞ in., as in the experimental work, and were drilled to a minimum depth of 20 ft. into the rock. The total linear feet of holes drilled at Woodstock Dike, including the experimental section, was 11,182, and at Glenford Dike 9,190.

The same general procedure was followed in grouting the holes as in the experimental grouting, but some changes were made. In order to economise in the labour incidental to the use of hand-pumping of grout, water pressure supplied by steam pumps was substituted for the Douglas hand pump, four grouting units being in operation at all times, with piping extending the full length of both dikes. As before, Cockburn-Barrow grout machines were used for mixing the grout, wooden troughs conveying it to hollow iron cylindrical pressure tanks.

These grout tanks consisted of 12-in. iron pipes, 4 ft. long, laid horizontally, two of which were mounted on a portable wooden truck. Suitable 2-in. pipes and fittings made it possible to use each tank alone or in sequence. Pressure, when required, was applied at one end by connection with the water line, and the grout in the tank was discharged by displacing it with water. This method was found to work very smoothly, resulting in a saving of time and more effective grouting on account of the continuous operation.

The grouting of the earth cover and embankment

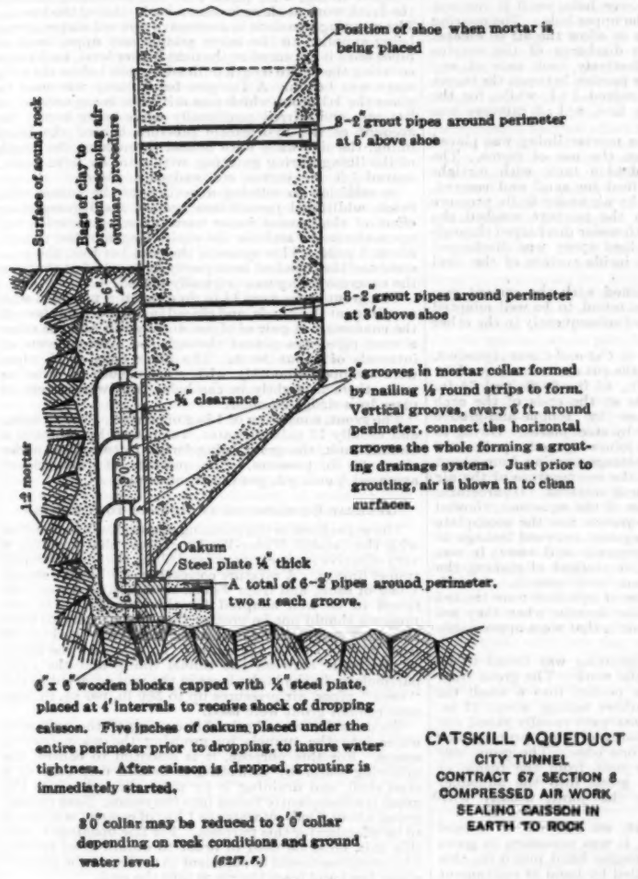

Position of shoe when mortar is being placed
8–2" grout pipes around perimeter at 6' above shoe
Surface of sound rock
Bags of clay to prevent escaping air ordinary procedure
8–2" grout pipes around perimeter at 3' above shoe
2" grooves in mortar collar formed by nailing ½ round strips to form. Vertical grooves, every 6 ft. around perimeter, connect the horizontal grooves the whole forming a grouting drainage system. Just prior to grouting, air is blown in to clean surfaces.
¾" clearance
1:2 mortar
Oakum
Steel plate ¼" thick
A total of 6–2" pipes around perimeter, two at each groove.
6" x 6" wooden blocks capped with ¼" steel plate, placed at 4' intervals to receive shock of dropping caisson. Five inches of oakum placed under the entire perimeter prior to dropping, to insure water tightness. After caisson is dropped, grouting is immediately started.
3'0" collar may be reduced to 2'6" collar depending on rock conditions and ground water level. (8217.F.)
CATSKILL AQUEDUCT
CITY TUNNEL
CONTRACT 67 SECTION 8
COMPRESSED AIR WORK
SEALING CAISSON IN EARTH TO ROCK

FIG. 7.

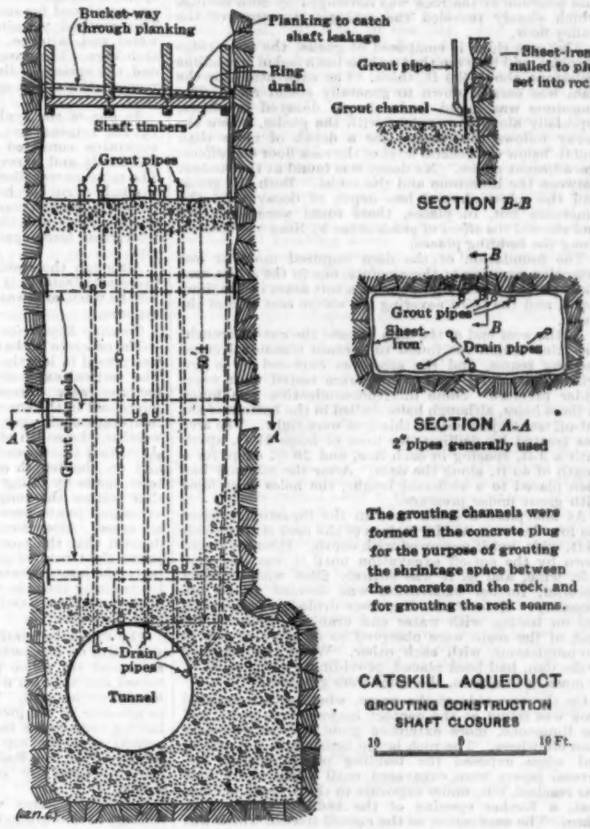


FIG. 8.

above the rock, at the Woodstock Dike, was completed before the rock was grouted. The row of 4-in. casing without the inner 2½-in. pipe, was grouted first, and then the other row, the grouting of cover to flow-line elevation being accomplished by raising the 4-in. casing as desired. After this cover grouting was accomplished, the 2½-in. casing was used to grout the rock. A total of 7,564 barrels of cement was used for grouting at Woodstock Dike, including the experimental section, and 5,613 barrels at Glenford Dike.

The results of the grouting at both dikes have been very satisfactory, the estimated reduction in seepage, with a full reservoir, being 75 per cent. at Woodstock Dike and 90 per cent. at Glenford Dike. In addition, the foundations under the dikes have been improved materially, due to the consolidation of the disintegrated rock and the filling up of the seams and cavities.

Grouting the Foundation under Kensico Dam.—Kensico Dam is a gravity structure of cyclopean concrete masonry, with a maximum height of 310 ft. above the bottom of the excavation. The dam is across the Bronx River, between parallel ridges which rise to a height of about 180 ft. above the bed of the river. At the site of the dam, the quality and attitude of the rock was developed by core borings which clearly revealed the geologic structure of the valley floor.

The east ridge is composed of gneiss, the west ridge of schist, and between the two hills lies a bed of crystalline limestone about 400 ft. thick. The excavation for the dam was carried down to generally sound rock. The limestone was found to be deeply decayed in places, especially along the contact with the gneiss, where the decay follows the contact for a depth of more than 100 ft. below the general level of the rock floor and affects the adjacent gneiss. No decay was found at the contact between the limestone and the schist. Both the gneiss and the schist showed less depth of decay than the limestone but, in places, these rocks were shattered and showed the effect of crush zones by lines of weakness along the bedding planes.

The foundation of the dam required more or less extensive grouting at three points, one in the schist near the west end of the dam, one at a soft seam in the limestone, and the third covering the entire east side of the gorge.

At the west end of the dam beyond the cut-off trench, the mica schist was found to contain occasional cross-bedding seams, and the area was explored by a few drill holes, 25 ft. deep, which were tested with water under pressure. Some intercommunication was found in these holes, although holes drilled in the bottom of the cut-off trench just east of this area were tight. The area was treated by drilling two lines of holes 11 ft. apart, with a 3-ft. spacing in each line, and 25 ft. deep, for a length of 40 ft. along the dam. After the masonry had been placed to a sufficient height, the holes were filled with grout under pressure.

At one place a crush zone in the limestone crossed the foundation. At the surface of the rock it was about 15 ft. wide, but it narrowed with depth. It was followed down by the cut-off excavation until it was less than 3 ft. wide, and as it was entirely filled with compact material, further excavation was deemed to be unnecessary. Holes 25 ft. deep were drilled over the area, and on testing with water and uranium, those to the west of the seam were observed to be more or less in communication with each other. When the masonry in the dam had been placed, providing a cover of 35 ft. or more in thickness, the holes were grouted.

On the east side of the gorge, where a disintegrated zone was found at the contact between the gneiss and the limestone, more extensive grouting was necessary than elsewhere. The rock lay in beds about 2 ft. thick, and when exposed the bedding planes opened up. Several layers were excavated until fairly sound rock was reached, but, under exposure to the air and summer heat, a further opening of the bedding planes took place. The excavation of the cut-off trench, which was carried down to a depth of 40 ft. below the general level of the excavation, had shown that several seams in the rock were open and water-bearing.

Holes, 25 ft. deep and about 25 ft. apart, were drilled normal to the inclination of the strata, and 2-in. pipes were fitted into them and extended up through the masonry. Two rows of holes were also drilled in the bottom of the cut-off trench near the sides, about 15 ft. apart, longitudinally. The tops of the lower holes in the gorge were at about elevation 65, and as they were not grouted until the concrete had reached elevation 102, the grout pipes were in some cases 125 ft. in length.

Pressure tests, using water coloured with uranium, were made on each hole to determine the influence on the other holes. As a result of the tests, it was concluded that the cut-off trench effectively intercepted the more open seams, and that the grout pipes could be divided into three groups: First, the holes up stream from the cut-off trench, where they all appeared to connect freely with each other; second, the holes in the cut-off trench which evidently penetrated a region not reached by the others; and, third, all the holes down-stream from the cut-off trench, which were evidently quite freely intercommunicative.

In grouting, each of the three groups was treated separately. Usually, the pipe which took water most freely was the first to be grouted. As the grout appeared in other pipes, they were capped, and the pressure continued until the hole refused to take more grout. Then the pipe was capped, and connection was made to another pipe, the uppermost pipe being left open for a vent. Eventually, all the pipes were filled with grout, capped, and left embedded in the dam masonry. With the reservoir full for two years, there has been no indication of any leakage on the down-stream side of the dam.

MISCELLANEOUS GROUTING.

Mortar Lining inside of Large Steel Pipes.—Steel pipe syphons were used for crossing valleys along the line of the aqueduct where the rock was not sound or where, for other reasons, pressure tunnels would be impracticable. The steel pipes vary from 9 ft. 6 in. to 11 ft. 2 in. in diameter, and are lined with 2 in. of cement mortar, enveloped with concrete, and covered with an earth embankment. The mortar lining was placed in two operations: First, an invert about 8 ft. wide was placed in the bottom of the pipe, using a 1:2 mortar and finishing with a screed board and trowel; and, second, the portion above the invert was lined by using a wooden form built up of curved panels inside the pipe, and pouring grout from the surface of the ground through vertical 2-in. pipes screwed to the top of the pipe at 15-ft. intervals, one pipe being used to grout a 15-ft. section and the next for a vent.

The grout was mixed by hand on the surface in boxes arranged so that one batch would be mixed while the other was discharged. The grout was poured through the pipe screwed into the lower hole, until it ran out of the 4-ft. riser inserted in the upper hole. The pouring was continued for some time to allow the air to escape. This method permitted the discharge of the surplus water and laitance, and effectively took care of any shrinkage. The grout for the portion between the invert and the springing line was mixed 1:1, while, for the portion above the springing line, a 1:2 mixture was used.

In one of the syphons, the mortar lining was placed by the cement gun, without the use of forms. The apparatus consisted of a double tank with airtight bulkheads and a revolving feed for sand and cement. The mixture was discharged by air under 40 lb. pressure through a rubber hose. As the mixture reached the nozzle, it came in contact with water discharged through another hose, and the combined spray was discharged with great force against the inside surface of the steel pipe.

Although the results obtained with the cement gun were satisfactory, it was not found to be well adapted for the work, and was not used subsequently in the other syphons.

Grouting Expansion Joints in Cut-and-Cover Aqueduct.—The concrete in the arch of the cut-and-cover aqueduct was placed in lengths of 30 ft., 45 ft., 60 ft. and 75 ft. The vertical expansion joints at the ends of the arch sections were formed either by tongue-and-groove joints cast in the concrete, or by steel plates. Owing to temperature changes, these joints opened up in cold weather, the width of the openings varying from about $\frac{1}{32}$ in. to $\frac{1}{2}$ in., depending on the temperature of the air and on the length of the arch sections. Hydrostatic tests, made by filling portions of the aqueduct, showed that neither the tongue-and-groove nor the steel-plate expansion joints were tight against outward leakage in all cases. After some experiments and tests, it was decided that the most effective method of making the joints tight was to grout them with cement. Accordingly, the joints in several miles of aqueduct were treated by grouting them in the winter months when they are open the widest. Only the joints that were appreciably open were grouted.

The following method of grouting was found to be successful on one section of the work: The grout from a 2-quart tin coffee pot was poured into a small tin funnel and through a ¼-in. rubber tubing, about 12 in. long, into the joint. The joints were usually raked out in advance of the grouting, using a 12-in. pruning saw having very coarse teeth on one edge. The grout was poured near the top of the joint, from the inside of the aqueduct, the leakage of grout into the aqueduct being stopped by caulking the joint, usually with oakum.

Where the joints were wet, on account of inward leakage due to ground water, it was necessary to grout them by pressure, using a Douglas hand pump for this purpose. They were first drilled by hand at convenient points, and into the holes were inserted ¾-in. pipe nipples, 6 in. long, threaded at one end. The nipples were caulked into the joints with lead wool, and the inside edges of the joints were also caulked with the same material.

The mix generally used for grout poured into place was 5 parts of cement to 8 parts of water by volume. This consistency was found to be a little too thick for the hand pump and, for the wet joints, a mix consisting of 3 parts of cement to 8 parts of water was used. The grouting was very effective in making the joints tight against leakage.

Grouting Caving Ground in the Grade Tunnel.—In driving one of the headings of the Reynolds Hill Tunnel, several slips occurred, and, in a 15-ft. stretch, the timbering was badly distorted by the slide. In order to excavate safely the bench through this section, the space outside the timbering which had previously been dry packed, was grouted. Concrete was first placed back of the timbering for a height of about 4 ft. above the wall plates and, at each end of the section, concrete cut-off walls were built as high as possible between the lagging and the rock, the closures being made with brick masonry. The dry-packed space over the arch between the cut-off walls was then grouted by a tank grouting machine. More than 30 cub. yards of 1:1 grout were placed. No trouble was experienced subsequently in excavating the bench through this section.

Grouting in Tunnel where Concrete Lining had Disintegrated.—Some time after it was placed, the concrete lining in a portion of the Eastview Grade Tunnel was found to be undergoing a progressive, slow disintegration, caused by the infiltration of the surrounding ground-water which contained certain chemical elements injurious to concrete. The portion of the tunnel affected, a stretch of about 1,700 ft., was relined with brick 12 in. thick.

To take care of the water seeping through the concrete lining, sheets of steel were used throughout the side-walls and arch of the lined section, and kept uniformly away from the concrete face by ordinary spruce plaster lathe, to provide drainage and grouting space. Before the brick lining was placed, a bituminous water-proofing fabric was deposited on the sheet metal water-stop and on the invert concrete.

Along the centre line of the invert in the lined section, a 4-in. tile pipe was laid with open joints to receive the drainage water. Transverse drainage grooves cut in the invert conveyed the water from behind the metal stop to the centre line drain. This drain was provided with 2-in. pipes, 12 in. long, extending up through the brick lining on the invert. Before grouting the space behind the water-stop, this drain and the connecting grooves were pumped full of grout, connections being made to the 2-in. pipes in the invert.

For grouting between the metal stop and the original concrete lining, 2-in. pipes were set, extending through the brick work at three levels on both sides of the tunnel. The grouting was done in successive upward stages, grout being supplied to the lower middle and upper level of pipes until it appeared at the next higher level, each stage covering the entire length of lined section before the next stage was begun. A Douglas hand pump was used to place the 1:1 grout which was mixed in boxes carried on flat cars and stirred continually while being used. On account of the hydrostatic pressure behind the brick lining, the side-walls were braced throughout the length of the lining during grouting, with 4-in. by 6-in. struts, spaced 5 ft. on centres, and wedged in place.

In addition to relining a portion of the tunnel with brick, additional precautions against the disintegrating effect of the ground water were taken by grouting the space above the arch for the entire length of the tunnel, about 1 mile. This space in the roof between the concrete and the rock had been partly dry packed at the time the concrete lining was originally placed.

The grout pipes were 1½ in. in diameter, provided with couplings at their ends, and placed in holes drilled through the concrete. A pair of pipes, one a grout and the other a vent pipe, was placed through the arch concrete at intervals of about 50 ft. The inner ends of all pipes were wrapped smoothly with cotton cloth in order to make them fit tightly in the holes, and were driven in place by a sledge-hammer.

The grout, consisting of 1 bag of cement, 1 bag of sand, and usually 12 gals. of water, was placed by means of a Canniff tank, the grout being forced in to refusal under about 90 lb. pressure. The quantity of grout placed averaged ½ cub. yd. per lin. ft. of tunnel.

GENERAL CONCLUSIONS IN REGARD TO GROUTING.

The experience in the grouting operations in connection with the Catskill Water-Works, showed that grouting is very effective for backing up, and filling the spaces behind, tunnel linings. A mixture consisting of 1 bag of cement, 1 bag of sand, and from 6 gals. to 8 gals. of water, was found to be well adapted for this purpose. The air-pressure should not be greater than is necessary to force the grout into place. The pressures actually used varied from 30 lb. to 90 lb. per sq. in. To complete the filling of the voids between the tunnel lining and the rock, particularly in the high places in the roof adjacent to the "vent" pipes, air pressures up to 300 lb. per sq. in. and neat cement grout were used.

Good results were obtained in cutting off the leakage of water into the tunnels by grouting the water-bearing seams. For this purpose, it is essential to control the inflowing water by collecting it behind drip-pans or a steel shell, and draining it by pipes through which the grout is subsequently forced into the seams. Neat cement grout, about 6 gals. of water to 1 bag of cement, was found to be effective for this purpose. For fine openings a very thin mix must be used in order to obtain good results. The pressures should be sufficient to overcome the ground-water head and force the grout into the rock.

In sinking wet shafts, grouting was successful in cutting off leakage. The best results were obtained by alternately drilling and grouting, using holes about 10 ft. to 15 ft. deep in the bottom of the shaft. The consistency of the grout should be adjusted to the size of the seams. In some cases, a little addition of bran, oats, &c., to the neat cement grout will aid in plugging the crevices in the rock.

The results obtained in treating the foundations of dams and in cutting off leakage underneath the dikes by drilling holes and grouting the rock seams under the dam structures were satisfactory. It is desirable in such cases to explore the rock under the dams thoroughly by diamond drill borings for the purpose of locating weak zones and open seams. The location of the holes and method of grouting will depend on the natural conditions encountered.

In conclusion, it should be stated that the procedure to be adopted in any grouting operation must take into account all the factors that enter into the problem. No one method is applicable to all cases. The conditions encountered during the grouting may make it advisable to modify the procedure materially. Good judgment and skilful adaptation to meet varying conditions are essential to a successful conclusion.

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THE CHEMICAL AND THERMAL CONDITIONS IN BLAST-FURNACE PRACTICE.*

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THE object of this paper is to place in the hands of those engaged in the manufacture of pig-iron a plain statement of the chemical and thermal conditions governing blast-furnace practice. The subject cannot be approached without a reference to the monumental work of Sir Lowthian Bell, which forms the foundation of our knowledge of the scientific side of blast-furnace work. Subsequent progress has been more in regard to the conclusions drawn from observed facts than in the discovery of any new fact.

The reactions in a blast furnace are two-fold—chemical and thermal. Chemical reactions are primarily connected with the reduction of iron and other elements forming pig-iron, and the interaction between iron oxide, metallic iron, carbon and the oxides of carbon forming furnace gases. Thermal reactions are necessarily associated with these chemical reactions, so that the heat developed or lost during them cannot be separated from them, but in a blast-furnace there are further thermal requirements connected with the melting of iron and slag, the maintenance of correct hearth temperature, and losses by radiation, &c. These are purely thermal factors. The net result of chemical reaction is insufficient to provide the necessary heat. In furnaces working upon pure ore and pure fuel chemical considerations may become a dominating influence, but in general blast-furnace practice this is not the case.

Generally speaking, the necessity for thermal effects requires the combustion of fuel beyond any limitation prescribed by chemical considerations. In furnaces where every chemical action is being carried on in the most advantageous manner possible, we have still to expend fuel, as the necessity for increased heat is occasioned by impurity in the fuel or ore, by a fall in blast temperature, by an increase of moisture in the blast, or by any other cause calling for extra thermal requirements, with the result that purely chemical considerations are, to that extent, exceeded.

As all reactions in the blast furnace which lead to the combustion of carbon to carbonic acid are strictly limited by chemical considerations, it follows that as the necessity for direct thermal effect increases, or diminishes, after the chemical limit is reached, the carbon used or saved can only be considered as burnt to monoxide. To avoid any confusion upon the point it is perhaps necessary to explain this matter fully.

The combustion of carbon beyond monoxide inside a blast furnace can only be ascribed to two main chemical causes: (1) Dissociation of carbon monoxide into carbon and carbonic acid; (2) the reduction of metallic iron from its oxide by carbon monoxide yielding carbonic acid. In the regular working of a furnace cause (1) is limited by carbon entering the pig-iron, because if carbon is deposited, and does not find an outlet, it descends to the tuyeres and is burnt again so that deposition and recombustion become cyclic. Only in a hanging furnace where proper working is suspended can deposition of carbon exceed the amount found in the pig-iron, and cause any effect on the amount of carbonic acid in the escaping gas beyond that point. Therefore deoxidation of the iron oxide provides the chief source of carbonic acid in any furnace in normal work, and it can only be supplemented, to the limit stated, from the other source. Carbonic acid once formed has to remain in equilibrium with carbon monoxide, carbon, and reduced iron, which equilibrium is governed by temperature. Exposed even to the hardest coke at temperatures exceeding 900 deg. C., carbonic acid cannot exist permanently. Sir Lowthian Bell proved by experiments Nos. 78 and 79 that, even exposed to reduced iron, 40 per cent. is destroyed at about 650 deg. C., and about 60 per cent. at 800 deg. C. Therefore above 900 deg. C. carbonic acid leads a transient existence. As the temperature falls below this point, or below a point, which probably varies with each kind of coke or fuel, it becomes possible for more carbonic acid to exist until at another point, also probably varying with each kind of coke or fuel, the action ceases and carbonic acid can pass away unchanged. The limits of this range with such fuel as the author has experimented upon does not usually exceed 300 deg. C., and is at most 400 deg. C.

Thus the general condition is that carbonic acid when formed has to run the gauntlet of hot fuel and hot reduced iron, and although the simultaneous presence of excess of monoxide exerts a protective influence, it is quite impossible that the full theoretical amount shall escape in the gases. Therefore the amount of carbon burnt to carbonic acid per ton of pig-iron cannot exceed a definite limit in the normal working of a furnace, but it may very easily fall considerably below it. The highest amount the author has found in the regular working of any furnaces at any time has been equal to 5·8 cwt. of carbon per ton of pig-iron. The lowest has been 4·8 cwt. of carbon per ton of pig-iron. There exists, however, an instance of under 4 cwt., which will be dealt with later.

It follows that in any normal furnace, even if there be a limit which chemical considerations demand causing it to be necessary for a certain excess of monoxide to exist (so that the maximum possible carbonic acid can exist), once that point is passed, and through impure fuel and material or from any cause increased thermal effect is required, the ratio of carbon oxides becomes governed by thermal requirements, and not by chemical considerations. This leads to the main conclusion. If there be a chemical limitation to this ratio of carbon oxides, then once it be exceeded all further carbon can be burnt to monoxide only. In any furnace where the ratio exceeds the limit (which it must be clearly understood comprises all normal furnaces working upon coke) any thermal effect required, or saved, must be measured in carbon burnt to monoxide only.

In regard to the point of chemical limitation referred to, the author has unfortunately never had under his observation a furnace in which this needed consideration. The evidence points, however, to the fact that although there may be chemical considerations which render impossible the production of the equivalent of 5·8 cwt. of carbon per ton of pig-iron as carbonic acid, thermal considerations make it possible in certain cases with pure fuel and pure ore to sacrifice carbonic acid with economy to fuel consumption. Such an instance already referred to is given in Sir Lowthian Bell's paper "On the Waste of Heat, Past, Present and Future, in Smelting Ores of Iron." The case is that of a furnace producing iron on 12·6 cwt. charcoal = 10·31 cwt. carbon, where, although chemical limitations rendered the carbon as carbonic acid as low as 3·96 cwt. per ton of pig-iron, yet because the ore and fuel were pure and the thermal requirement low the furnace produced iron with that low consumption of carbon. The chemical limitations adapt themselves to give the best thermal result, and this case proves beyond all doubt that the governing factor in fuel economy is not, in the main, chemical, but depends upon the thermal side of blast-furnace work. If we assume some coke ash, or sand, or siliceous rock, and limestone to be added to the charge of this furnace, the increased thermal effect required would call for extra carbon to be burnt to monoxide; this would assist the chemical influences and make it possible for more carbon to exist as carbonic acid, which the extra carbon monoxide produced would preserve. Therefore in such a case increase of fuel is nominal until the full amount of carbon as carbonic acid is reached, after which it would become excessive. In such a furnace hotter blast would yield no great saving, but if the limit of carbon as carbonic acid were reached (and beyond that carbon was being burnt to monoxide) hot blast would yield a great saving up to that limit and much less beyond that.

The instance is quoted more particularly to show that the chemical influence only becomes predominant when the ore and fuel are so pure that thermal effort is reduced to a minimum.

We may sum up the combustion of fuel in a blast furnace as follows:—

(1) Chemical reactions render it possible for not exceeding 5·8 cwt. carbon as carbon monoxide to be further burned to carbonic acid.

(2) Chemical reactions involved in the decomposition of carbonic acid from material, and in the process of direct reduction of metallic oxide or metalloids, form carbon monoxide without air being necessary.

(3) The combustion of carbon at the tuyeres by air, and oxygen from the moisture it contains, is, apart from the use of hot blast, the only other means available of making good any heat required after the above reactions have been fully carried out.

The usual modification is that No. 1 is not fully carried out when the corresponding oxygen has to be dealt with as in case No. 2. This may be due in the normal case to the coke being more susceptible to attack by carbonic acid, but may also be due to the ore being less easily reduced. The latter cause seems to be entirely neglected as a factor in blast-furnace economy, and the author would illustrate the matter by quoting the following experiments carried out in a large retort where ores can be maintained at temperatures from 800 deg. to 900 deg. C. for several days exposed to furnace gases regenerated so far as CO content is concerned by previously passing them through a tube containing red-hot charcoal. Lumps up to 2 in. cube are operated upon, and in case a standard ore is exposed with each bath results are readily comparative. The figures represent the diminution of oxygen per equal iron in comparison:—

Well-burnt calcined Cleveland mine ...	90
Black centres of lump Cleveland mine ...	39
Scarred or fused and sintered Cleveland mine	21
Magnetic ore from a large deposit ...	19
Dense peroxide ore from a large deposit...	29
Good brown hematite from a large deposit	64

The author prefers not to specify the ores. The results agree with numerous similar experiments. Confirmation of the fact that ores vary in this respect can be found in the researches of Herr C. Schinz and Sir Lowthian Bell in the same direction.

It is fairly obvious that as these experiments represent a much longer exposure to more gas than they will meet in that part of the furnace where carbonic acid can exist, it will be quite impossible to find the maximum amount of carbon as carbonic acid from five out of the six cases, also that improper calcination of Cleveland ironstone can exert a considerable influence on the amount of carbonic acid likely to exist in the gases. Another point bearing upon the same matter is the reduction of carbonic acid by the action of hot fuel. Coke resists attack by carbonic acid better than charcoal, but charcoal furnaces show low fuel consumption, which goes to prove that diminution of carbonic acid by this cause is not a vital factor in fuel consumption.

The explanation the writer would give is that when carbonic acid is formed by reduction of iron oxide to iron the heat generated is almost absorbed in the reaction. Of course if the reaction does not take place the heat has to be provided elsewhere, but that does not affect the destruction of carbonic acid once formed. After the reaction, which must occur in the top 6 ft. or 8 ft. of the furnace charge (as carbonic acid can only exist in bulk there), any change or reduction of carbonic acid leading to heat absorption may exercise more of its influence in the direction of lowering the temperature of escaping gases than in lowering the temperature of descending material, which is the only way after the reaction has happened, and the carbonic acid is formed, that the change, could become a vital influence on fuel consumption. Most probably the decomposition of limestone carbonic acid exerts its influence in that way.

It may here be pointed out that the heat carried away by the escaping gases is not heat utilised, because it remains available outside the furnace and so far as the furnace is concerned has absolutely not been utilised.

This brings us to probably the most important and least understood of the functions of the blast furnace—the absorption of heat by the materials in their descent through the furnace. Yet interception is a vital function of the whole furnace and does not apply to a zone. My reading of Sir Lowthian Bell's statements does not convey the idea that he ever intended to imply any such limitation. Heat interception is one of the prime factors in hearth temperature, which is largely derived from the absorption of heat by descending material. The sum total of all changes, all irregularities, all chemical reactions show their combined effect in aggregate blast-furnace hearth temperature. There are only four sources of loss of heat: (1) Radiation and similar losses. (2) Escape of heat in the gases. (3) Heat in the metal. (4) Heat in the slag. Any deficiency must principally affect Nos. 2, 3 and 4. Reactions which occur near the furnace top may exert much of their influence upon the loss in the gases, and may not be so important in their effect upon hearth temperature as those near the well.

Anything which upsets the absorption of heat in the furnace, or the regular descent and mingling of materials with the ascending gases, exerts a tendency to cause loss. Amongst such causes are rapid local movement of descending material, or ascending gas: insufficient penetration of blast at the tuyeres; lack of capacity or time factor for the material to absorb heat; clogging or choking of a portion of the furnace space by fine ores; or by easily crushed fuel breaking down. All such causes lead to deficiency of heat absorption in larger or smaller quantities of material reaching the hearth, and in all cases to diminished hearth temperature requiring to be made good by burning more fuel. This remedy has the drawback that larger volumes of gas are produced, which pass at a proportionately higher speed over almost the same descending material, causing the heat of the escaping gases to rise and carry away more of the available heat.

The important conclusion to be gathered from the foregoing remarks is that the chemical composition of fuel must exert a large influence, because in a normal blast furnace with coke as fuel ash, sulphur, and the limestone required to flux them, lead to the loss of the heat the carbon yields. Slag is formed requiring fusion. Limestone carbonic acid carries away carbon, and from the gross heat developed we have in addition to deduct that which is carried away in the escaping gases. When the coke added or deducted beyond the limit spoken of previously is only burned to monoxide there are some very large percentage deductions to be made for impurity in fuel.

Reference to Table I (page 633) showing the heat supplied by burning pure carbon to monoxide by the hottest possible blast proves that per unit of carbon burned to monoxide only 70 per cent. or so of the gross heat remains available. Table II shows that when burned to carbonic acid nearly three times the heat is available. Table III shows the effect when burned by metalloids. The net result inside the furnace are:—

	Cwt. Heat Units.
Carbon burned to monoxide, net yield per unit	2,595
Carbon burned to carbonic acid, net yield per unit...	7,600
Carbon burned by metalloids, &c., net yield per unit...	2,015

Upon a furnace making Cleveland iron from 48 cwt. of calcined mine and 9 cwt. limestone per ton of pig-iron the fuel is required to provide inside the furnace:—

	Cwt. Heat Units.
Reduction of 18·37 cwt. iron × 1,747	32,092
Reduction of metalloids, say	6,697
Melting 20 cwt. of pig-iron × 350 ...	7,000
Driving off limestone CO_2 9 × 430 units	3,870
Decomposing this 1·03 carbon × 3,240 units	3,337
Fusion of slag 24·43 cwt. × 550 ...	13,447
Heating limestone gases 4·81 cwt. × 0·247 × 300 deg.	357
	66,800

This we can call 67,000 units of heat and carbon has to be supplied equal to 0·7 cwt. entering the pig-iron and 1·03 cwt. destroyed by limestone carbonic acid.

Normal radiation is allowed as a loss in calculating the net effect of carbon burned by Tables I, II, III.

Carbon required if the maximum of CO_2 is retained:—

	Cwt.	Cwt. Heat Units.
Enters pig and burned by limestone CO_2	1·73	
Burned to CO_2 × 7,600 units ..	5·80	= 44,080
Burned by other O in material × 2,015 units	1·20	= 2,418
To balance burned to CO × 2,595 units	7·90	= 20,502
Total	16·63	67,000

On exactly the same lines let us now assume the substitution of carbon by Coke A, 10 per cent. ash and sulphur, or Coke B, 15 per cent. ash and sulphur, but in

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other respects equal. Table IV shows Coke A has 84·2 per cent. of available carbon, Coke B only 78·8 per cent., while in Coke A the available carbon yields 211 less units and Coke B 308 less units than pure carbon because of ash, sulphur and impurity.

The effect applied to the same case as considered for pure carbon becomes :—

	Coke A. Cwt.		Coke B. Cwt.	
Enters pig and destroyed by limestone CO_2	2·06		2·20	
Heat for impurity in corresponding coke	0·18		0·29	
		Cwt. Heat Units.		Cwt. Heat Units.
To replace 5·8 carbon to CO_2	6·88	= 42,856	7·36	= 42,294
To replace 1·2 carbon to CO	1·45	= 2,185	1·52	= 2,048
To balance as carbon to CO	10·95	= 21,979	12·59	= 22,658
		67,000		67,000
Total coke	21·52 cwt.		23·96 cwt.	

What 16·63 cwt. of pure carbon can do requires Coke A, 21·52 cwt. and 1·61 cwt. extra limestone, Coke B, 23·96 cwt. and 2·40 cwt. extra limestone.

This is the minimum adverse effect, because we have taken the maximum of carbon to carbonic acid, and have made no allowance for a rise in the heat carried away by the gases, or possible increase of radiation, &c., through lower output.

Precisely the same applies to extra gangue matter in the ore. The example stated applies to Cleveland mine with 38·3 per cent. iron. Table II shows the extra heat requirements set up by using 36 per cent. mine requiring :—

Coke A $\frac{\text{Cwt. Heat Units.}}{5,514 / 2,007} = 2·74$ cwt. extra coke + 0·44 cwt. for limestone.

Coke B $\frac{\text{Cwt. Heat Units.}}{5,550 / 1,802} = 3·08$ cwt. extra coke + 0·47 cwt. for limestone.

Also the effect of using 34 per cent. mine requiring :

Coke A $\frac{\text{Cwt. Heat Units.}}{10,986 / 2,007} = 5·47$ cwt. extra coke + 0·88 cwt. for limestone.

Coke B $\frac{\text{Cwt. Heat Units.}}{11,058 / 1,802} = 6·13$ cwt. extra coke + 0·94 cwt. for limestone.

Thus we get in the case of the three different fuels and different qualities of mine under ideal conditions :—

	Carbon. Cwt.	Coke A. Cwt.	Coke B. Cwt.
Mine 48 cwt. per ton pig-iron	16·63	21·52	23·96
Mine 51 cwt. per ton pig-iron	19·10	24·70	27·51
Mine 54 cwt. per ton pig-iron	21·59	27·87	31·03

Table VI is constructed from the figures in the other tables to show approximately how net heat is developed and used by hot blast, coke, iron manufacture, and slag from ore, as graphically as possible on a furnace smelting 36 per cent. Cleveland mine. It will be seen that blast heat is responsible for 44 per cent. of the total heat the true combustion of coke leaves in the furnace. The beneficial reactions arising from the production of pig-iron (principally the formation of CO_2 from CO) neutralises a large amount of the gross heat required, so that pig-iron only requires 2·23 cwt. coke plus 14,341 net units = approximately 35 per cent. of the heat to be made good.

Slag from ore and limestone is all dead loss. The fuel burned to melt it provides the excess of CO existing above chemical limitations, and below the point of chemical limitation it helps the CO_2 to exist and is probably more helpful then. Otherwise it destroys 1·64 cwt. coke and 26,447 net units.

If the chemical limitation of CO to CO_2 is 100 to 55 with the carbon from limestone in the gases 18·3 cwt. of coke would cover it. Therefore 6·4 cwt. of coke is squandered in melting slag, and there is no remedy if the excess slag is there.

Table V shows that 6·4 cwt. of coke are capable of developing 12,845 net heat units. That is approximately two-thirds of the gross heat brought in by hot blast. Therefore in effect the excess of slag neutralises two-thirds of the advantage of applying hot blast, of the appliances to heat the blast, and of gases otherwise surplus now used to heat the blast. Not only so, but the 6·4 cwt. of coke correspond to 5·39 cwt. carbon out of 17·49 cwt. burned by air blast without which only 12·1 cwt. would require to be so burned; therefore more blowing engines, more boilers, and more gases to heat the boilers which would otherwise be surplus are wasted. Otherwise output is lowered.

The object of this is to show that much past ingenuity and invention can be nullified altogether by increasing the impurities in ore and fuel, and if we do not stop this tendency to increase, further possible improvement cannot cope with it.

These figures may be considered hypothetical to some extent, but when the writer came to the conclusions set out in this paper in 1902 a diagram was kept showing the working of a three-furnace plant with two units in work. The furnaces take 90 per cent. of their coke from adjoining ovens fed by the owners' own collieries, and there has been no very marked change. When the diagram was constructed it was based on 1 cwt. of coke being equal to 2 cwt. of calcined mine plus limestone per ton of pig-iron. The diagram represents actual half-yearly figures without any allowance, and the effect of all stoppages, strikes, &c., which can be shown to account for some of the variations is included. The war period has provided a deviation from normal which makes this diagram rather convincing.

It appears to be somewhat ignored to-day that none of the improvements which may be possible in blast-furnace practice can reverse these effects which follow on additional impurity as night follows day. Coke consumption per ton of iron has been and is steadily increasing in spite of all improvements which have been already made.

So far as the author has been able to ascertain there has been only one public advocate of the necessity of picking out siliceous gangue instead of putting it through the furnace at great loss. He refers to the late Mr. T. C. Hutchinson, who strongly insists upon this point in his papers before this Institute.

None of the fuel economy specialists have dealt with this side of the question as it deserves. Coal and ironstone miners take no interest in keeping down the harmful shale, stone and dirt. It is time that, so far as blast-furnace economy is concerned, this should be understood to be a vital matter involving the future of our iron trade, and through that to some extent the prosperity of our country.

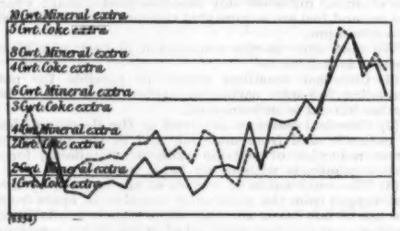
The illustrated effects of impure ore apply in greater degree to hæmatite practice, because, as can be seen

DIAGRAM OF ACTUAL FIGURES ON TWO FURNACES EACH HALF YEAR AND EFFECT OF INCREASED MATERIAL UPON COKE CONSUMPTION.

Coke-Broken Line.

Calcined Mine, other Ore & Limestone-Continuous Line.

On the Basis that within the Diagram 2 Cwts. Mineral = 1 Cwt. Coke per Ton Pig.


10 Cwt. Mineral extra.
5 Cwt. Coke extra.
8 Cwt. Mineral extra.
4 Cwt. Coke extra.
6 Cwt. Mineral extra.
3 Cwt. Coke extra.
4 Cwt. Mineral extra.
2 Cwt. Coke extra.
2 Cwt. Mineral extra.
1 Cwt. Coke extra.

from the analyses of slag shown further on, silica in such practice needs more limestone to deal with it, so does coke impurity.

It is necessary in the interests of fuel economy that attention should be given to cleaning coal for blast-furnace coke manufacture. It is not an economical proposition to pay coking costs upon increased ash and sulphur. It is also necessary to do something to exclude as far as possible shale, stone, clay and siliceous matter from our blast-furnaces. Those blast-furnace or other experts who consider silica a good thing in ore may be reminded that they can get all the benefits it gives by putting old firebrick or the like on the furnace burden without paying freight and the cost of ore.

If nothing can be done in these directions, instead of talking of the time when poorer materials will come in it is necessary to provide rich ore to mix in and maintain a standard enabling the blast-furnace to yield reasonable output with reasonable fuel consumption, because if it is not done we shall require to build more furnaces, stoves and blowing engines, in effect to work on slag alone, if the present output is to be maintained.

It is of course necessary that the surplus gas from blast-furnaces following the introduction of gas-blowing engines in place of existing steam-engines should be made full use of, so that in future we may look upon the blast-furnace as largely a gas producer in which fuel per ton of iron has ceased to be the dominating factor, as the excess fuel comes into use in other directions.

The author would, however, strongly urge the necessity for providing a rich, easily reducible ore to cope with the future situation upon the ground that output and quality of product will always require attention. In many cases the standard of quality in a lean ore cannot be greatly improved without casting aside as waste a considerable quantity of iron with the rejected siliceous matter. The provision of such rich ore would prevent the waste of some of this iron and, without prejudicing existing output and fuel consumption, conserve our existing mineral supply by bringing it into use.

It has been shown that 34 per cent. material requires 5 cwt. more pure carbon burned by air than 38 per cent. material. This involves 37 per cent. increase in the total blast per ton of pig. Even if the engines can blow that much more air, output will fall because the extra material has to be got down the furnace in resistance to the extra gas which has to pass up, and this will put further resistance on the engines and calls for more furnace capacity.

The point the author wishes to make quite clear is that the questions that No. 2 Committee on blast-furnace practice considered and reported upon, although of importance in equal cases, are all reduced to unimportant details if we have to face a 3 per cent. or 4 per cent. drop in iron content of our ore mixture or 5 per cent. extra ash in our coke. The tendency at present is in this direction.

Having pointed out that carbon, especially as coke, cannot be burned to provide heat without much of that heat being lost, blast heat on the other hand is a clear gain. Table I shows that 800 deg. blast heat, less equivalent radiation, provides 1,000 net units out of 2,595 available when the carbon is burned to CO, or out of 7,600 when it is burned to CO_2. The first 100 units raises the heat available by burning carbon with cold blast much more than the last 100 bringing it up to 2,595, and leads to a greater saving. The saving by dry blast in its effect must be precisely the same as blast heat. If dry blast excludes 60 per cent. of the moisture from normal air (which is all it might do in this country) it would save, according to Table I, probably 80 units per unit of carbon burned by blast, while as stated the hot blast brings in 1,000 units per unit of carbon, hence the average saving in this country will not exceed that arising from 100 deg. extra heat in blast.

As any water decomposed in the furnace shows as hydrogen in the gases, it would have been interesting if the papers published on dry blast had stated the percentage of hydrogen in the gases. In normal English furnaces working upon hydrated oxides the water decomposed in the furnace exceeds that which can come from decomposition of moisture in the blast, and there is in many cases a greater prospect of saving by driving combined water from the ore before it enters the furnace than in drying the blast. From the hearth of a hematite furnace the author has seen taken out a large lump of rubio ore 18 in. by 10 in. diameter, which, on breaking, gave off volumes of steam and showed the centre to be quite unchanged. When hematite was made from rubio ore upon a coke consumption of under 17 cwt. the hydrogen in the gases agreed with moisture in the blast, and seldom ran over 1½ per cent. by volume. Gases on furnaces now making double the output show over 3 per cent. In a special test over 14 days one furnace decomposed from the ore twice as much water as from the blast, and as drying the blast would only remove 60 per cent. of the moisture quite possibly three times the saving would result from driving off the combined water in the ore. In another specific case when the hydrogen normally ran 3 per cent. in the escaping gases a 2-hourly sample of gas was being continuously withdrawn when the furnace slipped lightly twice. The sample showed 6·3 per cent. of hydrogen by volume. A rapid sample withdrawn after a fairly heavy slip showed 9·2 per cent. of hydrogen by volume. There is no doubt this decomposition of water from the ore is a possible cause of so-called furnace explosions, as no furnace on dry material has ever to the writer's knowledge exploded.

Coming to purely chemical considerations, one or two text-book errors require correction.

Sulphur is not driven off by ordinary calcination, as the peroxide of iron under the conditions re-absorb it. The outside faces of lumps of Cleveland mine contain more sulphur than the centre. In burning purple ore bricks at high temperature with a sufficiently oxidising flame sulphur can be almost completely volatilised, but not so in ordinary calcination.

The effect of manganese upon sulphur is also a matter not correctly stated. It would be true to say that manganese helps in dealing with sulphur if we were allowed to put enough into the pig-iron, but the limit usually allowed in anything but basic iron is about 1½ per cent., and it is only when 1½ per cent. is exceeded that manganese is very beneficial in dealing with sulphur. As the use of manganese for steel works iron even in basic process is attended by loss in conversion, it is very doubtful if it can be classed as a helpful ingredient in ore. The effect of it on a normal hematite furnace in quantities which the market allows will be judged from the following figures representing all the analyses for two years on two hematite furnaces :—

—	Sulphur in No. 1 Iron.	No. 2 Iron.	No. 3 Iron.	No. 4 Iron.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Ordinary ores	0·0294	0·0492	0·0716	0·0992
Ordinary ores with some manganiferous ores ..	0·0276	0·0527	0·0749	0·0977

It can possibly be said that if the object in view is to keep sulphur in basic iron below 0·1 per cent. that 1½ per cent. manganese is very useful, but that is all that can be said.

On no branch of blast-furnace working has so much information which is quite inapplicable been published as upon the constitution of blast-furnace slags. One point essentially missed is that the blast furnace has to deal with gangue and sulphur as it finds them. Usually there is not much chance to vary, and the problem is to get rid of what does exist as satisfactorily as possible. In the Cleveland district it is no use pointing out the supposed disadvantage of alumina, because it has got to be dealt with.

Alumina has been classified as acid, base, and neutral. Some authorities regard increased alumina as accounting for all the troubles which arise; others regard deficiency in the same way. The writer is of opinion that it is confusion of effect with cause, to which blast-furnace observers seem particularly prone, which causes alumina ever to have been considered detrimental. The following is probably the true explanation. Where local ore has a very siliceous gangue and alumina chiefly comes from coke ash, increased gangue decreases the alumina. It causes by its increase the troubles which this paper set out to prove it did, but as analyses show deficiency of alumina the cause is lost in observing the effect. In

other places such as Northampton and Cleveland the gangue is silicate of alumina. Any increase of gangue producing the effects set out in this paper is certain to send up alumina in the slag, and again alumina gets the blame. In most cases alumina in the slag acts as the outward sign of increased gangue and is blamed for the effects that produces. If the cause be removed—increased gangue or increased necessity for thermal effect—better results will follow.

The author believes that published theory in regard to blast-furnace slags requires complete revision before a blast-furnace can in this respect be worked upon scientific lines. Viscosity or fusibility does not cause trouble when it can be altered by increasing or diminishing the base in the slag within limits. The limits are where the furnace blocks up with lime on the one hand and where the iron is not desulphurised on the other. As we proceed from the latter limit toward the former, coke increases and output decreases. Slag theory hardly fits the following cases, which represent in round figures the slags which Cleveland and Hematite furnaces in Cleveland have worked upon for years.

—	Calcium Sulphide.	Alumina.	Magnesia.	Lime.	Manganese Oxide.	Silica.
	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Cleveland	3	25	7	33	1	41
Hæmatite	4	16	4	43	2	31

Upon comparison it seems certain that alumina in the Cleveland slag takes the place of lime in the other, but theoretically as a base alumina should replace 1·65 times its equivalent as lime. Working on theoretical lines we should either have to take 9 per cent. of lime out of the Cleveland slag, in which case nothing but white iron high in sulphur would result, or else add 9 per cent. of lime to the hematite slag, when the furnace would choke up with lime.

We require an altogether new theory to put this slag question on a satisfactory scientific footing. The fact probably is that in metallurgical slags some definite fusible silicate acts as a vehicle carrying the other bodies in solution. The presence of one may negative the effect of another, but ordinary theories of chemical combination do not fit such slags while they are molten. Magnesia is a case in point. Theory says it replaces 1·4 times its weight of lime as a base, which is quite true at normal temperatures. There is evidence it does not do so in the blast furnace, and in the basic steel furnace slag it is quite certain that it does not.

The author recommends the practical blast furnaceman to keep to his present methods of working upon a slag which suits his furnace and the class of iron he requires to make, until the correct theory is evolved.

The only other point requiring special notice is a suggestion to use oxygen in the blast furnace to the total or partial displacement of air. Unfortunately even the use of oxygen does not make it possible to make one thermal unit into two, or one do the work of two. The blast-furnace problem is principally a thermal problem, and must be faced as such.

Directly we start to use oxygen to replace air we lose the heat brought in by nitrogen as hot blast. Of course we do not lose the heat it carries away in the gases, a dry oxygen might be used. The comparison between pure carbon burned by air and by oxygen at 800 deg. C. is as follows :—

	Air.	Oxygen.
Heat per 1 unit carbon	2430	2430
Heat in blast 800 deg. C.	1147	252
Gross ..	3577	2682

Reduced in useful effect by :—

	Air.	Oxygen.
Radiation, &c., 10 per cent. of gross	357	268
Decomposition of water	131	nil
Heat in escaping gases 300 deg. C. ..	494	179
Balance available	2595	2235

Apply this to the calculated figures showing carbon used on a furnace requiring 67,000 units, there is a loss of 360 units upon 13·7 cwts. of carbon burned by air, or 4,932 units ÷ 2,235 = 2·2 cwt. of extra carbon required, or 16·63 cwt. carbon on air, or 18·83 cwt. carbon on oxygen.

The iron tuyeres connection, &c., would burn up with oxygen at 800 deg. C., but the point is that if any benefit is to result this calculation should show it. When oxygen is tried it should be first applied where the blast does not exceed 300 deg. C., when the loss of heat in blast will be compensated by the other savings.

The explanations set out above are those which the author has found best fitted to explain differences in furnace results. The method does not show all the loss, or all the saving; there are always one or two further factors bearing upon the result which it is difficult to estimate truly. For instance, radiation and similar losses probably vary with time or output per day. The loss of heat in the gases must increase as coke increases and decrease as it decreases. The amount of total carbonic acid is never a fixed quantity per ton of pig-iron and varies in different cases. The result is that in general the method illustrated shows on these accounts rather less than the actual increase as thermal requirements increase, and also rather under-estimates the saving when they are decreased. The figures taken only apply to the specific case of Cleveland material, but the method set out can be amended so as to apply to any furnace working on any material, taking known conditions as a starting point.

It is desired to point out to the iron trade generally that blast-furnace fuel consumption depends primarily upon the amount of calcined material per ton of pig-iron, or the ratio of iron to inert matter in the ore. Lime should not be included in the estimate of inert matter in so far as it replaces limestone as a flux. As the iron in the ore falls, it is in all but exceptional cases replaced by siliceous matter, and as more ore per ton of pig-iron is required the siliceous matter per ton of pig-iron increases in a greater ratio than the percentage in the ore shows. It is not only a main factor influencing fuel consumption, but it also affects output, and the steady increase of impurity in fuel and ore is a very serious matter from the blast-furnace point of view. It is only a question of degree for this increase to nullify all the efforts at improvement in other directions which may be possible.

The writer is indebted to Messrs. Dorman, Long and Co., Limited for permission to place these facts before the Institute.

TABLE I.

Normal dry air taken as 76·976 per cent. nitrogen, 23·024 per cent. oxygen carrying 4 grains moisture per foot adds 0·64 oxygen, 0·08 hydrogen = 0·72 water vapour.

This will burn 17·75 units carbon to monoxide.

The products of combustion will be 76·98 units nitrogen, 41·42 units of carbon monoxide, 0·08 units hydrogen.

Assume the carbon to be burnt by air at 800 deg. C., that the products of combustion leave the furnace at 300 deg. C., and that one-tenth of the gross heat developed is lost by radiation, &c., in a normal furnace. Heat developed :—

Cwts.	Cwt. Units.	Cwt. Units per Unit Carbon.
17·75 C burnt to CO × 2430 units ..	43,132	2,430
76·976 N × 800° C. × 0·2586 SH = 15,888 units		
23·024 O × 800° C. × 0·225 SH = 4,144 units		
0·72 H_2O × 800° C. × 0·568 SH = 327 units		
= Heat in blast ..	20,359	1,147
Total	63,491	3,577

Reduced in useful effect as follows :—

	Cwt. Units.	Cwt. Units per Unit Carbon.
Radiation and other similar losses 10 per cent. of gross	6,349	357
Decomposition of water in blast 0·08 × 29,030	2,322	131
Heat escaping in gases at 300° C. ..	8,756	494
76·976 N × 300° C. × 0·247 = 5604		
41·42 CO × 300° C. × 0·247 = 3069		
0·08 H × 300° C. × 3·46 = 83		
Balance available inside the furnace ..	46,064	2595
	63,491	3577

Available for furnace work per cwt. of pure carbon 2595 cwt. units heat.

TABLE II.

If afterwards converted to CO_2 add 1 × 5670 = 5670 units.

	Cwt. Heat Units.
Deduct :—	
Radiation as before, 10 per cent.	567
1·33 units extra gases at 300° C. carry out, say	98
Extra heat available in furnace	5005

Available if further burnt to CO_2, 5005 cwt. heat units.

TABLE III.

Pure carbon burnt by reduction of metalloids instead of air.

	Cwt. Heat Units.
1 unit of carbon × 2430	2430
Deduct :—	
Radiation 10 per cent. of the gross	243
2·33 escaping gas carry out at 300° C., say	172
Extra heat available in furnace	2015

Available from carbon burnt by metalloids, 2015 cwt. heat units.

TABLE IV.

Per ton of coke :—

	Coke A. 10 per Cent. Ash, &c. Cwts.	Coke B. 15 per Cent. Ash, &c. Cwts.
Moisture and volatile	1·00	1·00
Carbon	17·00	16·00
Ash and sulphur	2·00	3·00
Limestone required for ash and sulphur ..	1·50	2·25
Ash, sulphur and limestone	3·50	5·25
Less limestone CO_2	0·62	0·93
Slag	2·28	4·32
Gross carbon as above	17·00	16·00
Less destroyed by limestone CO_2	0·16	0·24
Available carbon	16·84	15·76

Heat effects are taken up as follows :—

	Cwt. Heat Units.		Cwt. Heat Units.
For driving off water and heating to 300° C., say	750		750
Driving off limestone CO_2 limestone × 430	645		860
Decomposing this 0·16 × 3240 ..	518	0·24 × 3240	777
Fusion of slag 2·88 × 550	1584	4·32 × 550	2376
Heating CO to 200° × 0·78 × 0·247	58	300 × 1·17 × 0·247	87
	3555		4850
Compared with pure carbon :—			
Extra loss per unit available carbon	211		308

And available carbon is 84·2 per cent. and 78·8 per cent. of pure carbon.

TABLE V.

Different qualities of Cleveland calcined mine as compared with one requiring 48 cwts. per ton pig.

	36 per Cent. Iron. Cwts.		34 per Cent. Iron. Cwts.
Mine per ton pig	51·03		54·03
Extra mine or gangue	3·03		6·03
Requires extra limestone × 1¼	3·26		6·49
Total gangue and limestone	6·29		12·52
Less limestone CO_2	1·37		2·78
Extra slag	4·92		9·70
Carbone taken away by limestone CO_2 ..	0·37		0·74

Heat requirements :—	Cwt. Units.		Cwt. Units.
Driving off limestone CO_2 3·26 × 430	1,402		2,791
Decomposing this 0·37 × 3,240 ..	1,199		2,398
Fusion of slag 49·2 × 550	2,706	9·70 × 550	5,384
Raising CO to 300° C. 1·74 × 74 ..	129	34·7 × 74	257
Required for carbon as Coke A, 211 × 0·37 per cent.	78	211 × 0·74 per cent.	156
If Coke A is used	5,514		10,986
Add required for carbon as Coke B, 97 + 0·37 per cent.	36	97 × 0·74 per cent.	72
If Coke B is used	5,550		11,058

Available carbon in Coke A, Table IV, 84·2 per cent. Available heat.

Table I—Table IV.

2,595 − 211 × 84·2 per cent. = 2,007 per cwt.

Available carbon in Coke B, Table IV, 78·8 per cent. Available heat .. .. Table I. 2,595

Table IV.

308 × 78·8 = 1,802 per cwt.

TABLE VI.

Constructed to show 36 per cent. calcined Cleveland mines melted by coke, 10 per cent. ash, and sulphur.

Limestone for ore gangue 12·26 cwts. for coke ash 1·85 cwts. Coke 24·70 cwts. = carbon 21 cwts.

	Hot Blast.	Pig Iron.	Slag.	Coke.
Carbon enters pig iron ..	—	0·70	—	—
Carbon destroyed by CO_2 of limestone	—	—	1·40	0·21
Carbon burnt to CO by oxygen of ore	—	1·20	—	—
Leaving 17·49 cwts., carbon burnt by air.				

Combustion develops :	Heat Units.	Heat Units.	Heat Units.	Heat Units.
5·8 cwts. C to CO_2 from CO × 5,670 units	—	32,886	—	—
1·2 cwt. C to CO by oxygen of ore	—	2,916	—	—
17·49 cwts. C to CO by air ..	20,061	—	—	42,501
Gross heat	20,061	35,802	nil	42,501
Deduct loss in gases at 300° C. and 10 per cent. radiation, &c.	2,006	4,354	486	12,961
Nett heat left in the furnace ..	18,055	31,448	minus 486	29,540
Heat required :—				
Decomposition of moisture in blast	—	—	—	2,291
Driving off limestone CO_2 ..	—	—	5,272	795
Decomposing limestone CO_2 ..	—	—	4,536	681
Melting slag	—	—	16,153	1,956
Reduction of metalloids ..	—	6,697	—	—
Reduction of iron	—	32,092	—	—
Fusion of iron	—	7,000	—	—
Driving off coke moisture, &c., and heating to 300 deg. C. ..	—	—	—	919
Heat consumed ..	nil	45,789	25,961	6,642
Net heat available as above ..	18,055	31,448	minus 486	29,540
Net surplus	18,055	—	—	22,898
Net deficiency	—	14,341	26,447	—

The overall net surplus being 165 units.

Thus :—

	Coke.	Limestone.		
Blast heat shows ..	nil	nil	18,055 units	net surplus.
Coke combustion shows	20·83 cwt.	1·85 cwt.	22,898 units	net surplus.
Pig-iron manufacture shows	2·23 cwt.	nil	14,341 units	net deficiency.
Slag from ore shows ..	1·64 cwt.	12·26 cwt.	26,447 units	net deficiency.

"THE N.P.L. REVIEW."—There must be a very considerable number of persons who have been at some time or other more or less closely connected with the National Physical Laboratory at Teddington, and, having severed their connection, are still desirous of keeping in touch with the inner working of that Institution. A convenient means of doing this is now available in the form of magazine, bearing the above title, which it is proposed to issue six times per annum. The first number, which made its appearance in November last, contained biographical sketches of Sir Richard Glazebrook and the new director, Professor J. E. Petavel, as well as articles on topics of general interest, official notices, sports fixtures and departmental notes. The latter are of particular interest to outsiders as they indicate the general lines in which the various departments are working and also call attention to any noteworthy developments in each case. Similar matter appears in the two subsequent issues in which the standard reached in the first number is well maintained. The magazine will be sent post free for a subscription of 7*s.* per annum, and communications concerning it should be addressed to Mr. H. B. Irving, National Physical Laboratory, Teddington, Middlesex.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

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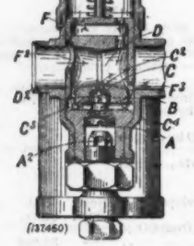
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

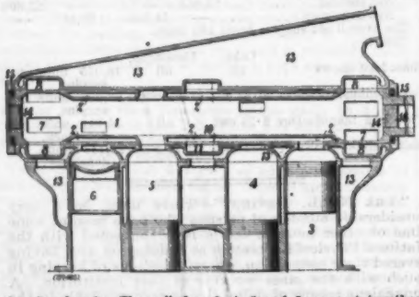
GAS ENGINES, PRODUCERS, HOLDERS, &c.

137,460. F. H. De Veulle, Birmingham. Carburettors. (6 *Figs.*) May 10, 1919.—The invention relates to carburettors. According to the invention, in the wall of the shaped passage is a chamber containing a fuel sprayer, which sprayer receives its supply through a restricted orifice. This sprayer chamber communicates with the interior of the passage through an aperture and with the inlet and outlet ends of the passage through ducts in the wall of the passage, a notch in the throttle controlling the outlet duct. The fuel is fed through a restricting nipple A^2 to a well A, into which screws a jet nozzle B. Above this jet nozzle is a small mixing chamber C, in which is generated a rich mixture. This mixing chamber communicates with the interior of the shaped passage D through an orifice immediately over



the jet nozzle, through which the fuel passes. Below the fuel level, and on the air inlet side of the carburettor, a duct C^3 leads from the mixing chamber to a slot D^2, whereby it communicates with the air intake E through the hole F^2 in the sliding throttle F, when the latter is in its lowest positions. There is also a similar duct C^4 below the top of the jet nozzle on the outlet side of the carburettor which communicates with the induction pipe under the control of a slot F^3 in the throttle sleeve. When the throttle sleeve is nearly shut, air is drawn along the first duct D^2 and C^3, and is carburetted in the mixing chamber and the resultant mixture travels along the second duct C^4. Some mixture may also pass out through the outlet C^4, as is shown by the arrows. (*Sealed.*)

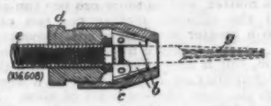
137,485. T. B. Tutton, Bath. Valve Mechanism. (3 *Figs.*) June 27, 1919.—The invention relates to rotary valves for internal-combustion engines comprising an internal cylindrical chamber for receiving the exhaust from the cylinders and an induction chamber concentric with said exhaust chamber, the two chambers being arranged for revolution together as one body. A valve made in accordance with the invention is adapted for use with monoblock cylinder castings for vertical cylinders, the valve extending laterally beyond the cylinders at both ends with exhaust ports from the central chamber at each end, the inlet ports communicating with an annular chamber in the cylinder head. The rotary valve comprises, in one casting, a cylindrical exhaust chamber 1 and an induction chamber 2, which is concentric with



the chamber 1. The cylinders 3, 4, 5 and 6 are cast together in one block. At each end of the valve are exhaust ports 7, which deliver the exhaust from the chamber 1 to chambers 8, to which the exhaust outlet pipes are connected. About midway lengthwise of the valve is a series of inlet ports 10 arranged in a circular row at intervals apart in the outer wall of the chamber 2. These ports communicate between the chamber 2 and an annular channel 11 in the cylinder head. The channel 11 communicates with the induction pipe. The cylinders and cylinder head are cooled by water contained in the water spaces 13. The valve is closed at each end by plugs 14. Any end play is borne by thrust races 15. The valve is rotated from the crankshaft by a drive transmitted to the shaft 16. (*Sealed.*)

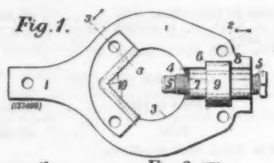
MACHINE AND OTHER TOOLS, SHAFTING, &c.

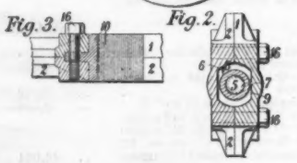
136,608. C. Hall, Walsall. Chucks. (2 *Figs.*) December 13, 1918.—The invention has relation to chucks for tapping and drilling machines of the type comprising a series of jaws for gripping the tap contained within a cone shaped nose to an outer casing of the chuck, which jaws are caused to grip the tap by screwing up the coned casing, an element being assembled intermediate the end of the driving spindle and the interior of the jaws, to provide a positive drive between said driving spindle and the tap. The outside casing is provided with a coned nose within the interior of which are jaws *b*, which are retained apart by coiled expansion springs *c*. The rear end of the casing is internally



screw-threaded to receive a cap *d*, which has a central tapped hole for screwing on to the screw thread of the spindle *e* of the machine. A disc is provided at its centre with a square hole, which is adapted to receive the square end of the tap *g*, while the end of the spindle *e* is adapted to bear against the disc, so that as the outer casing of the chuck is screwed further on to the cap *d*, the jaws are forced further into the cone, and thereby grip the body of the tap *g* while the square end of the tap is positively connected to the disc. (*Sealed.*)

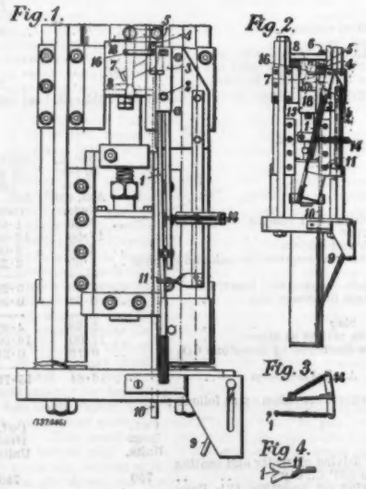
137,408. H. Smith, Sheffield. Lathe Dogs. (4 *Figs.*) February 19, 1919.—The invention relates to lathe dogs of the kind employed to assist in transmitting power from the lathe to the work. The dog is made in two main parts 1 and 2 which are clamped together by set screws 16, the division of the dog being across the axis of the aperture 3 which receives the work to be rotated in the machine. The hole 4 for the set screw 5 to clamp the work in the aperture 3 is made sufficiently large for the set screw 5 to pass freely through it. The hole 4 is formed





partially in both of the two main parts of the dog and at a convenient part of its length is enlarged into a recess 6. A renewable tapped nut 7 for the clamping set screw 5 is provided and is enclosed in the hole 4 and recess 6 between the two members. The nut 7 is held against longitudinal movement by means of a collar 8 formed thereon and engaging the recess 6. Rotation of the nut in relation to the dog is prevented by forming the collar 8 with flats 9, engaging corresponding flat parts of the recess 6. A renewable gripping piece 10 is provided. (*Sealed.*)

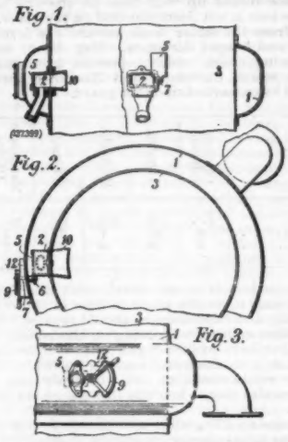
137,446. W. Bailey, Birmingham. Power Press Guards. (8 *Figs.*) April 14, 1919.—The invention relates to safety guards for power presses, said guards being of that type comprising a swinging lever operated from a moving part of the machine. The guard comprises a vertical lever 1 carrying a plate 17 at its lower end and pivoted near its upper end at 2 to a part of the fixed frame, so as to be adapted to swing in a lateral direction across the workspace of the press. Above the pivot 2 the lever is extended into a short arm 3, which is engaged upon one side by the forward turned-down end 4 of a horizontal



lever 5 pivoted at 6, and whose rear end is bent downwards and laterally, and formed into a hook 7, which is adapted to be engaged by the clutch operating lever 8, coupled to the clutch hand lever 9 by a rod 10, so that when the said hand lever is actuated to throw the clutch into engagement the horizontal lever 5 is turned about its fulcrum so as to operate the guard lever 1, causing the latter to swing across the work space. As the plunger descends the front face of the pitman 15, or an extension piece 18 thereon, engages and operates a bell-crank lever 16 engaging a slot in the upper end of the guard lever 1, and so completes the movement of the guard and maintains the latter across the work space when the hand lever is returned to its normal position. The guard 1 is returned against a stop 11 by means of two springs, one connected between the guard 1 and one arm of a horizontal lever 14, and the other between the second arm of said lever 14 and a suitable fixed part. (*Sealed.*)

MINING, METALLURGY AND METAL WORKING.

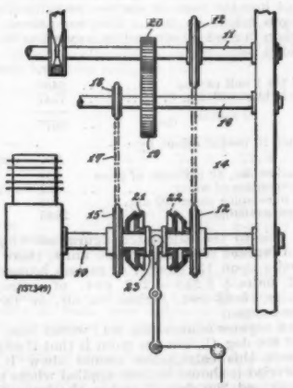
137,399. W. H. Wood, Birmingham, and D. H. Wood, Birmingham. Cupolas. (3 *Figs.*) August 2, 1919.—The invention pertains to cupolas or melting or heating furnaces, and it has for its object the improvement in the supply and the regulation of the air blast. A single air belt 1 is arranged around the cupola, a set of four tuyere boxes 2 being arranged thereround in the same plane. The air-belt is formed from pressed steel, and is trough-shaped in cross-section, such air belt being riveted to the wall 3 of the cupola. A separate air belt is provided for each row of tuyeres. The tuyere boxes 2 are fitted with an adjustable shutter 5 for regulating the supply of blast.



The shutter is pivoted centrally to lug 6 of the tuyere box, and is operated by a spindle 7 which passes through the outer wall of the belt. A handle is fitted on the end of this spindle and can be moved and retained in any desired position in a quadrant 9, thereby enabling the shutter to be readily controlled from the outside. The sides 10 of the tuyere box incline outwardly towards the inside of the cupola at a suitable angle. A pivoted sight device carrying the mica disc is fitted on the belt opposite each tuyere box, such device being mounted on a fitment 12 which also carries the quadrant. When the sight device is opened on the pivot an aperture is uncovered in the air belt, thus giving access to the tuyere box. (*Sealed.*)

MOTOR ROAD VEHICLES.

137,349. F. J. Sabel, London. Change-Speed Gearing. (1 *Fig.*) May 28, 1919.—The invention relates to change-speed gearing for machinery, motor vehicles and the like of the type in which a pair of expanding cone pulleys are provided mounted upon parallel shafts with means in connection therewith whereby the pulleys are operated simultaneously in such a manner that when one opens the other closes, in combination with gear whereby a reversal of motion may be obtained when desired. According to the invention, there is combined with the gear of the type specified, a reversing gear. 10 is the engine shaft, the motion from which is transmitted to the shaft 11 through the



medium of sprocket wheels 12, 12, and chain 14. A further sprocket wheel 15, mounted upon the shaft 10, transmits motion to a lay shaft 16 through the medium of chain 17 and sprocket wheel 18. This lay shaft is supported upon a swinging frame and carries a toothed wheel 19. By means of a lever, the lay shaft may be raised or lowered so as to bring the wheel 19 into or out of mesh with a pinion 20. The sprocket wheels 12 and 15 normally run loose upon the shaft 10, but are brought alternately into engagement with it by means of clutch members 21 and 22 which are caused to engage corresponding members on the sprocket wheels by the movement of a sliding sleeve 23, which is formed integral with the clutch members. (*Sealed.*)

CARRIAGE OF DANGEROUS GOODS AND EXPLOSIVES IN SHIPS.—The Board of Trade has recently issued a reprint of the 1915 booklet, dealing with the transport in ships of dangerous goods and explosives. The chief amendments relate to the carriage of inflammable liquids, calcium carbide, ferro silicon, and sulphur dioxide. Additions have also been made to the notes on other dangerous substances. The booklet is published at the price of 1s. net at H.M. Stationery Offices.